L2.2002-64
University of Alberta Library
0 1620 3415483 9

CHEMISTRY 20

Module 7

Organic Reactions

Learning Technologies Branch

Alberta LEARNING

Library and Archives Canada
Bibliothèque et Archives Canada

Chemistry 20

Module 7

Organic Reactions

Learning Technologies Branch

Alberta LEARNING

Chemistry 20
Module 7: Organic Reactions
Student Module Booklet
Learning Technologies Branch
ISBN 0-7741-0904-1

Cover photo: PhotoDisc, Inc.

This document is intended for	
Students	✓
Teachers	✓
Administrators	
Home Instructors	
General Public	
Other	

You may find the following Internet sites useful:

- Alberta Learning, **http://www.learning.gov.ab.ca**
- Learning Technologies Branch, **http://www.learning.gov.ab.ca/ltb**
- Learning Resources Centre, **http://www.lrc.learning.gov.ab.ca**

The use of the Internet is optional. Exploring the electronic information superhighway can be educational and entertaining. However, be aware that these computer networks are not censored. Students may unintentionally or purposely find articles on the Internet that may be offensive or inappropriate. As well, the sources of information are not always cited and the content may not be accurate. Therefore, students may wish to confirm facts with a second source.

ALL RIGHTS RESERVED

Copyright © 1993, 2001, the Crown in Right of Alberta, as represented by the Minister of Learning, Alberta Learning, 11160 Jasper Avenue, Edmonton, Alberta T5K 0L2. All rights reserved. Additional copies may be obtained from the Learning Resources Centre.

No part of this courseware may be reproduced in any form, including photocopying (unless otherwise indicated), without the written permission of Alberta Learning.

Every effort has been made both to provide proper acknowledgement of the original source and to comply with copyright law. If cases are identified where this effort has been unsuccessful, please notify Alberta Learning so that appropriate corrective action can be taken.

IT IS STRICTLY PROHIBITED TO COPY ANY PART OF THESE MATERIALS UNDER THE TERMS OF A LICENCE FROM A COLLECTIVE OR A LICENSING BODY.

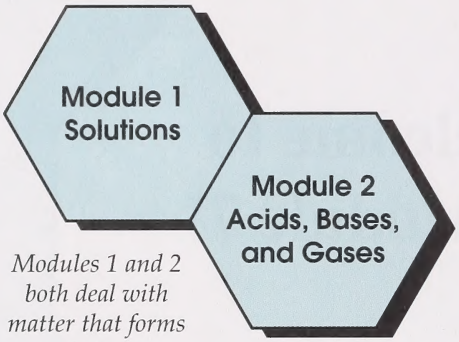
UNIVERSITY LIBRARY

Welcome to Module 7!

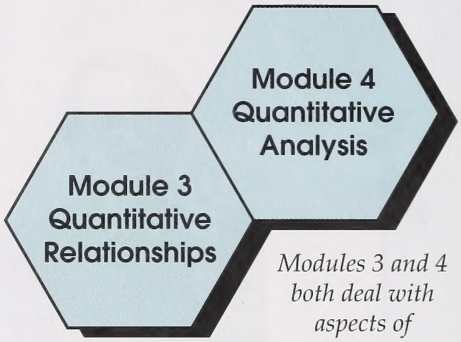
We hope you'll enjoy your study of *Organic Reactions*. Remember, to make your learning a bit easier, several videocassettes and laser videodiscs are referred to throughout the modules. Your textbook *Nelson Chemistry* will also enhance your studies.

COURSE OVERVIEW

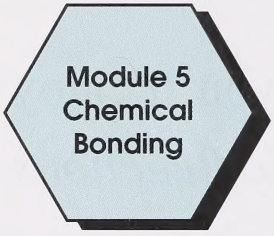
This course contains seven modules. The module you are working in is highlighted in deeper colour.

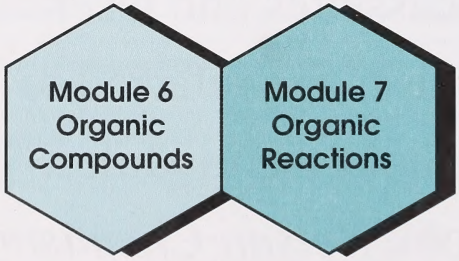


Modules 1 and 2 both deal with matter that forms solutions.



Modules 3 and 4 both deal with aspects of stoichiometry.





Modules 6 and 7 both deal with organic chemistry.

MODULE 7

Contents

Module Overview 1
Evaluation 2

Section 1: General Reactions 3

Activity 1: Substitution and Addition 4
Activity 2: Hydrocarbon Combustion and Elimination 10
Activity 3: Esterification 16
Follow-up Activities 22
Extra Help 22
Enrichment 24
Conclusion 25
Assignment 25

Section 2: Polymers and Applications 26

Activity 1: Polymerization 27
Activity 2: Reactions and Systems 37
Activity 3: Careers and Applications 42
Follow-up Activities 51
Extra Help 51
Enrichment 53
Conclusion 54
Assignment 54

Module Summary 54

Course Survey for Chemistry 20

Appendix 55
Glossary 56
Suggested Answers 56

Digitized by the Internet Archive
in 2017 with funding from
University of Alberta Libraries

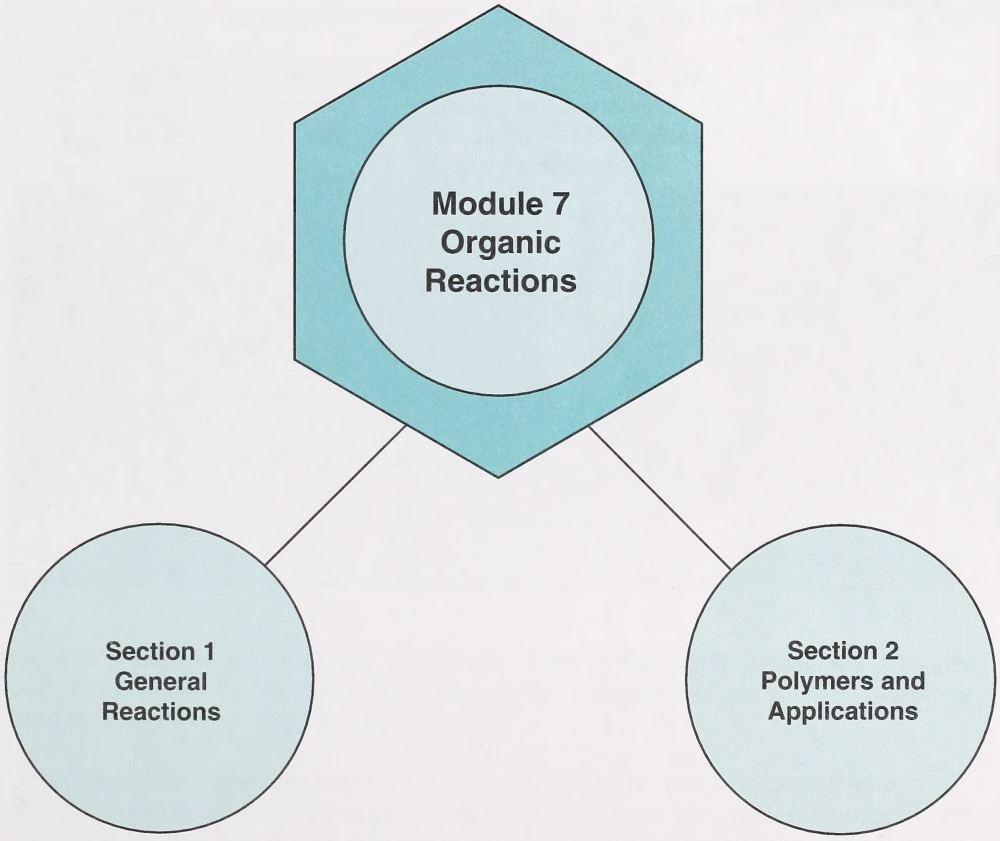
https://archive.org/details/chemistry2007albe_2

MODULE OVERVIEW

Have you ever wondered about the types of reactions that occur in your body every moment of every day? Thousands of reactions are occurring constantly to keep you walking, talking, and functioning in good order.

How do the drugs you take for illness really work? What chemical changes occur on the surface of your skin when you apply lotions or cosmetics? The reactions of organic molecules play a crucial role in many aspects of your life.

In Module 6, you were introduced to the variations that can be found in the structures and names of organic molecules. In this module you will look at simple organic reaction types and discover how much you depend on these reactions.



Evaluation

The document you are presently reading is called a Student Module Booklet. It will show you, step by step, what to do and how to do it.

This module, Organic Reactions, has two sections. Within each section, your work is grouped into activities. Within the activities, there are readings and questions for you to answer. By completing these questions you will construct your own learning, discover scientific connections, and apply what you have learned. The suggested answers in the Appendix of this Student Module Booklet will provide you with immediate feedback on your progress.

In this module, you will be directed to the accompanying Assignment Booklets. You are expected to complete two Assignment Booklets for this module. Your grading in this module is based upon the assignments that you submit for evaluation. The mark distribution is as follows:

Assignment Booklet	
Section 1 Assignment	**45 marks**
Assignment Booklet	
Section 2 Assignment	**55 marks**
TOTAL	**100 marks**

Assignment Booklet

When you see this icon, turn to the appropriate Assignment Booklet to find the assignment questions for that section.

SECTION 1

General Reactions

Organic molecules are composed of a variety of atoms that can be arranged in a number of different ways. Do you know how these varied compositions occur? This section of Module 7 will help you answer this question.

You may not have thought to compare your body to an automobile, but both burn organic molecules to obtain energy. Many of the reactions that occur in your body and the reactions used in industry are extensions of simple organic reactions. This section will help you look at simple organic reactions and some of the applications for these reactions.

ACTIVITY 1

Substitution and Addition

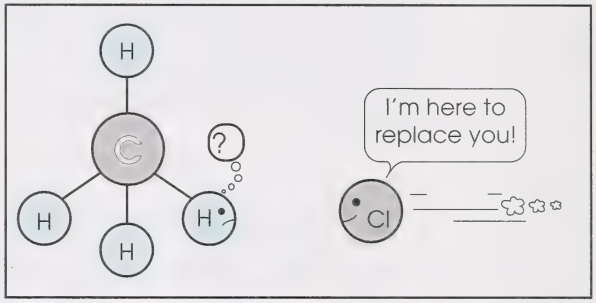
Substitution Reactions

One type of reaction that some organic molecules can go through is substitution.

1. What does the term *substitution* mean to you?

substitution reactions – reactions that involve the replacement of a hydrogen atom or functional group with another functional group

Substitution reactions in organic chemistry involve the replacement of one atom by another. Industry uses this type of reaction to produce many of the organic substances you use today.



Nelson CHEMISTRY

As an introduction to substitution reactions, read the bottom third of page 258 and the top third of page 259 of your textbook.

2. Study the example reaction given in your textbook involving propane in a substitution reaction.

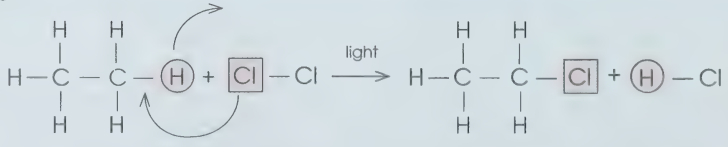
   a. What atom replaces one of the hydrogens on the propane molecule, C_3H_8?

   b. What is needed to make the propane substitution reaction occur at a noticeable rate?

   c. Write the propane substitution reaction using condensed structural diagrams as you used in Module 6. (**Note:** The term *structural formula* can sometimes be used instead of *structural diagram*.)

3. How is a substitution reaction with benzene similar to a reaction with an alkane?

Example



Note: It takes a **whole** chlorine molecule to substitute **one** chlorine atom onto an alkane or benzene molecule, and two products are formed.

4. You wish to substitute three atoms of chlorine onto propane.

   a. How many molecules of chlorine would this reaction take?

   b. How many molecules of HCl would you produce in this reaction?

   c. Write the reaction using molecular formulas only.

Check your answers by turning to the Appendix, Section 1: Activity 1.

The type of substitution reaction you have just examined, the replacement of a hydrogen by a halogen (F, Cl, Br, or I), can be represented by the following general equation.

Substitution

$$\underset{\substack{\text{alkane}\\\text{or}\\\text{benzene}}}{R-H} + \underset{\text{halogen}}{X_2} \xrightarrow{\text{light}} \underset{\substack{\text{organic}\\\text{halide}}}{R-X} + \underset{\substack{\text{hydrogen}\\\text{halide}}}{H-X}$$

where R = alkyl group or benzene ring
X = F, Cl, Br, I

The general rule for substitution reactions is that there is only one atom replaced at a time.

5. Use your model kit to perform the following reactions. Then write the reactions with complete structural diagrams. Give only one organic halide product for each case.

   a. $CH_4 + Br_2 \rightarrow$

   b. $C_2H_6 + I_2 \rightarrow$

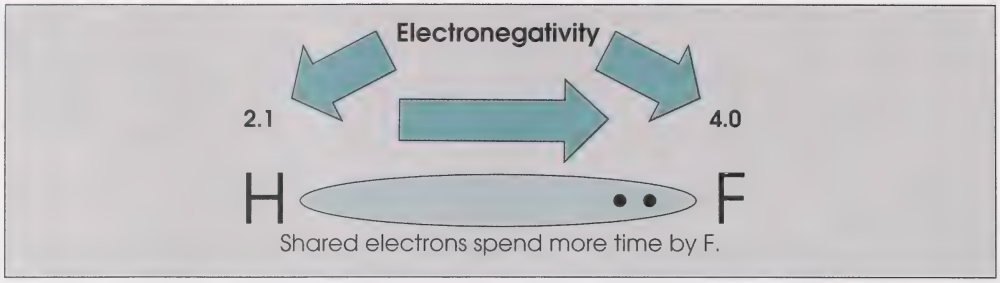
   c. butane + $Cl_2 \rightarrow$

   d. benzene + $Br_2 \xrightarrow{\text{catalyst}}$

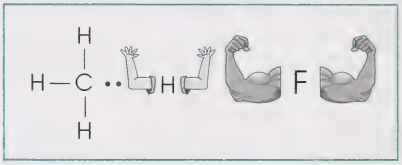
   e. _____ + _____ $\longrightarrow$ $\underset{\text{Cl}}{\underset{|}{CH_2}} - \underset{\text{Cl}}{\underset{|}{CH_2}}$ + _____

Check your answers by turning to the Appendix, Section 1: Activity 1.

From your reading you know that a halogen atom can replace the hydrogen atom with a little help from light, but is that all there is to it? In your discussions in Module 5 on bonding, you learned that there is a difference in the ability of various atoms to attract electrons. This ability is directly related to the concept of electronegativity, the tendency of atoms to attract or gain electrons when bonding.



Some atoms tend to attract electrons more strongly than others. This tendency plays an important role in the substitution reactions you have seen so far and will be more important in the next type of substitution reaction.



A second type of substitution reaction is the replacement of a halogen by another halogen. Figure 7.1 illustrates the general equation for this type of substitution.

R—X	+	HY	⟶	R—Y	+	HX
organic halide		hydrogen halide		organic halide		hydrogen halide

where X = one type of halide
Y = another type of halide

FIGURE 7.1: Substitution Reaction Involving Halogen Replacement

Example

CI_4	+	HBr	⟶	Cl_3Br	+	HI
tetraiodo-methane		hydrogen bromide		bromotriiodo-methane		hydrogen iodide

6. Use complete structural diagrams to illustrate the preceding example equation.

7. Since the order of the halogens from lowest to highest electronegativity is as follows,

$$I < Br < Cl < F,$$

what does the order mean in terms of which halogen can replace another halogen?

Check your answers by turning to the Appendix, Section 1: Activity 1.

Although there are other substitution reactions, the two types that you have studied are the only ones for which you are responsible. The two types of substitutions are summarized in Figure 7.2.

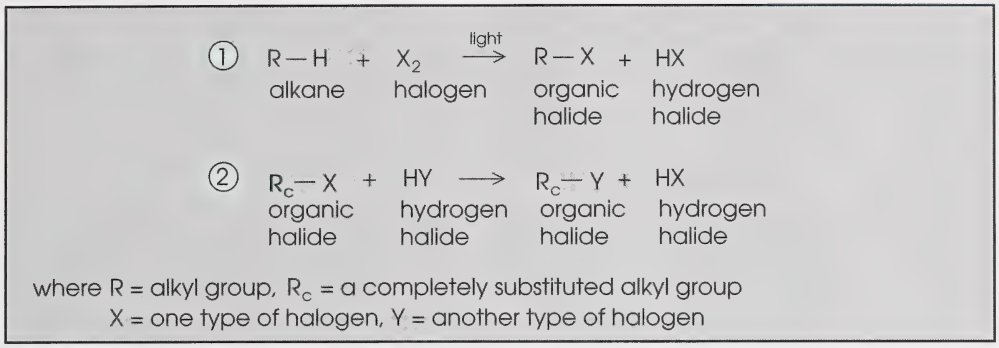

① R—H + X2 light R—X + HX
alkane halogen organic halide hydrogen halide
② Rc—X + HY Rc—Y + HX
organic halide hydrogen halide organic halide hydrogen halide
where R = alkyl group, Rc = a completely substituted alkyl group
X = one type of halogen, Y = another type of halogen

FIGURE 7.2: Substitution Reactions

You have seen how alkanes and benzene must undergo substitution reactions because of their saturated nature. But what happens if you want to react an organic compound that isn't saturated? And how are the substances such as the dry cleaning fluids and freons you examined in Module 6 actually formed?

Addition Reactions

If there was an empty space on a park bench, would someone have to get up before you could sit down?

Unlike alkanes, alkenes and alkynes have "spaces" that allow for various types of atoms to be attached. To see how the difference in structure of alkenes and alkynes creates variations in their reactions, read the bottom paragraph on page 257 and the top two-thirds of page 258 in your textbook.

Nelson CHEMISTRY

8. Why are **addition reactions** faster than substitution reactions?

addition reactions – reactions that add atoms to a molecule across a multiple bond

9. Give two examples of different types of atoms that can be added to multiple bonds.

10. Considering the number of atoms that can be added, what is the difference between alkenes and alkynes in addition reactions?

11. List *alkynes*, *alkanes*, and *alkenes* in the correct order from least reactive to most reactive.

12. Write a structural formula for the products in the following equation, showing both possible products.

$$CH_3-CH_2-CH=CH-CH_3 + HBr \longrightarrow \square \text{ or } \square$$

Check your answers by turning to the Appendix, Section 1: Activity 1.

hydrogenation – an addition reaction that adds two hydrogen atoms across a multiple bond

You have discovered that there is more variety in the types of molecules that can be added to multiple bond compounds than can be substituted on alkanes. One type of addition reaction mentioned in your textbook is called **hydrogenation**, where an alkane can be made from an alkene or alkyne using hydrogen.

Figure 7.3 is a summary of several possible addition reactions.

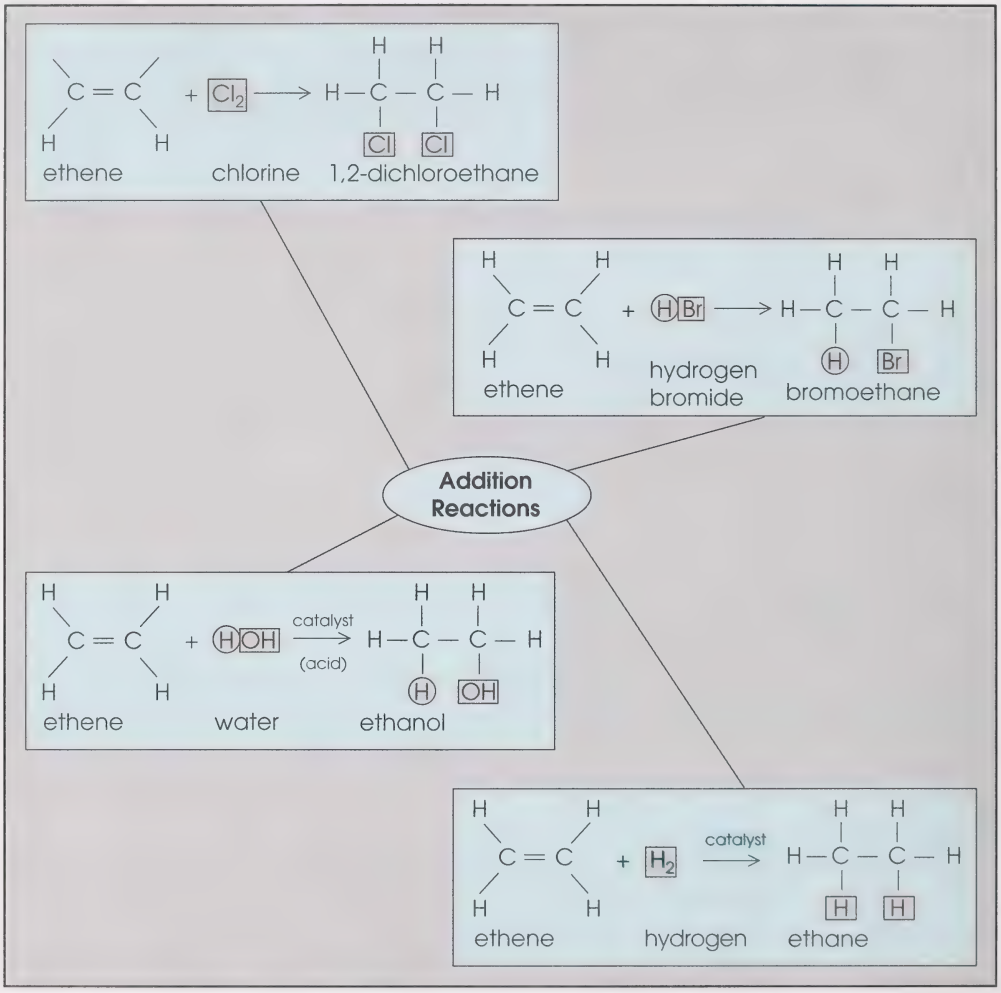


FIGURE 7.3: Addition Reactions

Please note that in Figure 7.3 alkyne examples could have been used as well. Ethene was used only for simplicity.

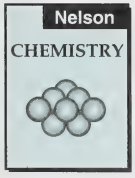
13. Catalysts were used in two of the reactions in Figure 7.3. What is a catalyst?

14. Compare substitution reactions to addition reactions by completing the following matching question. Write the appropriate roman numeral from the list of terms beside its proper definition. Use each term only once.

Definitions	Terms
a. a catalyst	i. I
b. replace one atom on a molecule, making two products	ii. addition reaction
c. Br will replace	iii. speeds up the reaction but is not consumed
d. place two hydrogen atoms on a molecule	iv. Cl
e. add two atoms to a molecule, making one product	v. substitution reaction
f. F will replace	vi. hydrogenation

Check your answers by turning to the Appendix, Section 1: Activity 1.

Chemists have improved their understanding of reaction types by using models. You can also obtain a better understanding of simple organic reactions by using your model kit. For the following questions construct the reactants in the equations. Complete the reaction by manipulating your models and writing down the reaction equation using structural formulas.



15. Do question 14 (a-g) on page 259 of your textbook.

16. The following reactions could be either substitution or addition reactions. Complete the reactions and indicate the reaction type. Use structural diagrams for the organic molecules.

a. ethene + bromine →

b. propene + H_2O →

c. ethene + hydrogen chloride →

d. + fluorine →

Check your answers by turning to the Appendix, Section 1: Activity 1.

In this activity you have studied simple organic reactions involving substitution reactions to single bonds and addition reactions to multiple bonds. In the activity that follows you will look at the formation of the double or triple bond by removing atoms of the organic molecule, the burning of organic molecules to produce energy, and the identifying of unknown organic molecules.

ACTIVITY 2

Hydrocarbon Combustion and Elimination

PHOTO SEARCH LTD.

Hydrocarbon Combustion

Observe a flame burning by lighting a match or a lighter, or look at the pilot light on a gas stove, hot water tank, or furnace.

1. What conditions are necessary for the flame to burn?

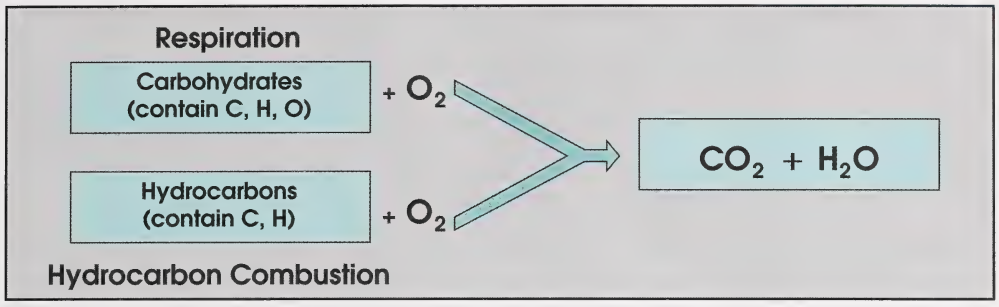
2. What products are given off by the flame?

Check your answers by turning to the Appendix, Section 1: Activity 2.

respiration – the process of carbohydrate breakdown in the body

hydrocarbon combustion – the burning of hydrocarbons in the presence of oxygen

Every day you are probably in contact with some system that is burning hydrocarbons to obtain energy. Can you think of some items that burn hydrocarbons? A butane lighter, a car, and your barbecue are good examples. Even your body burns carbohydrates, a close relative of a hydrocarbon, to produce energy and the same products as hydrocarbon combustion. Burning carbohydrates in your body is called **respiration**. Burning hydrocarbons outside your body is called **hydrocarbon combustion**.



3. What substance is necessary for burning to take place in any type of combustion?

The general equation for the complete burning of hydrocarbons is as follows.

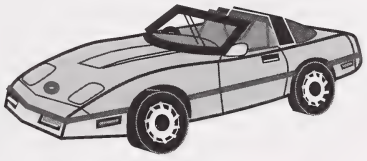
R—H	+	$O_{2(g)}$	⟶	$CO_{2(g)}$	+	$H_2O_{(g)}$	+	energy
hydrocarbon		oxygen		carbon dioxide		water		

where R = an alkyl group

Hydrocarbon combustion reactions can be simple, as in your gas barbecue,

$$2\ CH_3CH_2CH_{3(g)} + 5\ O_{2(g)} \rightarrow 3\ CO_{2(g)} + 4\ H_2O_{(g)} + \text{energy},$$

propane — oxygen — carbon dioxide — water vapour

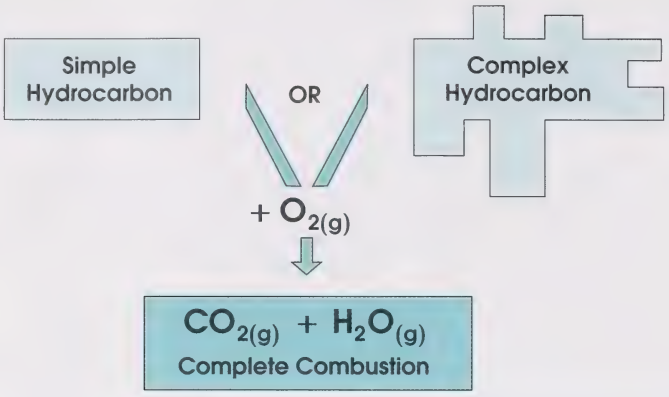


or more complex, as in the burning of 2,2,4-trimethylpentane in your car,

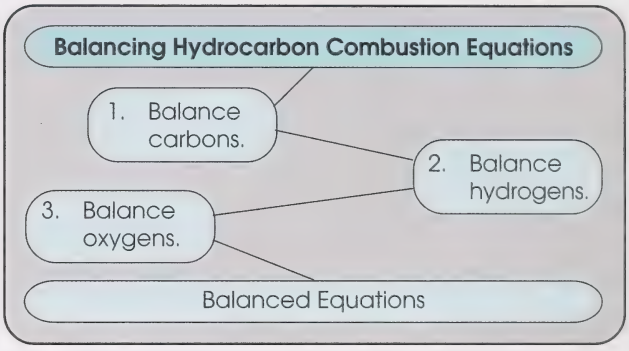
$$2\ CH_3-\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\underset{|}{\overset{|}{C}}}}-CH_2-\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{|}}CH-CH_3 + 25\ O_{2(g)} \rightarrow 16\ CO_{2(g)} + 18\ H_2O_{(g)} + \text{energy}$$

2,2,4-trimethylpentane — oxygen — carbon dioxide — water vapour

What is the same in both simple and complex reactions?



In Science 10 you were introduced to balancing hydrocarbon combustion equations using molecular formulas like $C_3H_{6(g)}$ for the hydrocarbon. Even though you are now familiar with and use the structural formulas of hydrocarbons, the balancing process is still the same.

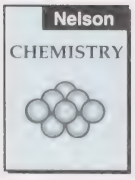


4. Write the balanced equation for the complete combustion of heptane. Use the molecular formula for heptane.

5. Write the balanced equation for the complete combustion of 2,5-dimethyl-3-hexene. Use the condensed structural diagram to represent the hydrocarbon.

Check your answers by turning to the Appendix, Section 1: Activity 2.

Hydrocarbon refinement is a big industry in Alberta. Many Alberta companies supply people and industries with their basic hydrocarbon needs, such as natural gas, gasoline, motor oil, and aircraft fuel. You are probably already aware that the oil taken from the ground does not immediately provide all of these needs. The oil requires several processes of refinement, depending on the oil make-up and the needs of society.



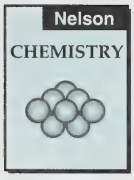
To more fully understand the processes involved in refining, read the section Petroleum Refining on page 241 to page 244 of your textbook. Then answer the following questions.

6. How does a fractional distillation tower separate the various hydrocarbons?
7. What is *cracking*? How is cracking accomplished and what is its importance?
8. What is *reforming*? What applications require reforming?
9. Compare combustion, cracking, and reforming by listing the conditions and events required for each reaction. Use a chart format for your answer.
10. How do the needs of society influence the amount of cracking and reforming that takes place?
11. To more fully understand the reforming process, use your molecular model kit to construct all the alkane isomers for the reforming reaction that combines propane and butane. Draw condensed structural diagrams for the isomers and name them. (**Hint:** What are the possible alkane isomers made with seven carbons?)

Check your answers by turning to the Appendix, Section 1: Activity 2.

Elimination Reactions

Have you ever watched bananas being picked? When bananas are picked, they are green. This prevents the bananas from rotting prematurely and allows them to be transported with less damage. But when you pick up bananas in the store, they are most often yellow and ripe. Have you ever wondered how they ripen so fast? The process of ripening many fruits is sped up by ethylene gas.



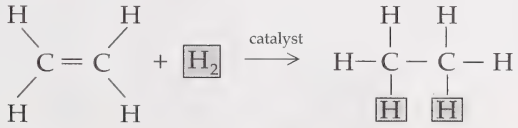
As Figure 9.22 on page 261 in your textbook suggests, this ethylene gas, or ethene gas, can be artificially produced by an elimination reaction. Your textbook describes two types of elimination reactions. Read the two short paragraphs about these reactions on pages 259 and 261 of *Nelson Chemistry*.

12. Using the two types of elimination reactions described in your textbook write your own example equation for each type.

elimination reaction – the production of multiple bond compounds through the removal of two or more atoms

reversible reaction – a reaction that can go in both directions

In Activity 1 you discovered one type of addition reaction called hydrogenation, represented by the following equation,



Do you think this reaction is **reversible**? In fact, the reverse of this reaction is called dehydrogenation, because of the removal of hydrogen. This is also an elimination reaction.

13. What is a common feature among the two types of elimination reactions described in your textbook and the preceding dehydrogenation example?

You discovered that in each of the preceding elimination reactions a double bond was formed. Elimination reactions are common ways of forming compounds such as ethene. As mentioned earlier, ethene (or ethylene) is a valuable compound in the produce industry. Later you will also learn the importance of ethene in the polymer industry, dealing with plastics and other synthetics. Can alkynes be formed in a similar manner?

As you can see in Figure 7.4, alkynes can also be formed from elimination reactions. The difference is that the triple bond formation requires harsher conditions.

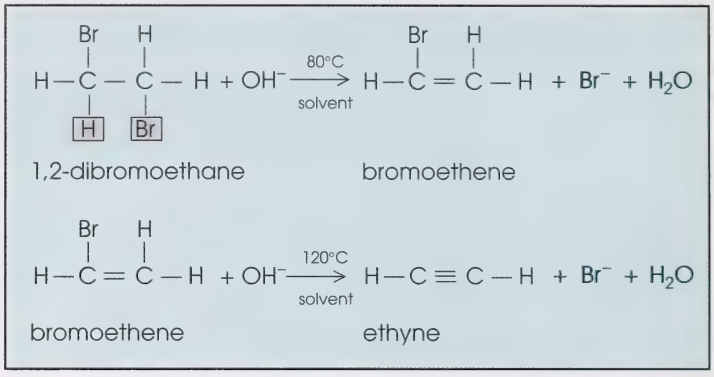

Br H
H—C — C — H + OH⁻ 80°C solvent H—C = C—H + Br⁻ + H₂O
H Br
1,2-dibromoethane
bromoethene
Br H
H—C = C—H + OH⁻ 120°C solvent H—C ≡ C—H + Br⁻ + H₂O
bromoethene
ethyne

FIGURE 7.4: Formation of Alkynes by Elimination

Nelson CHEMISTRY

14. To gain further practice in writing elimination reactions, answer textbook questions 15 (a, b) and 18 (a, b) from pages 260 and 262 of your textbook. Also use your molecular model kit to construct each reaction.

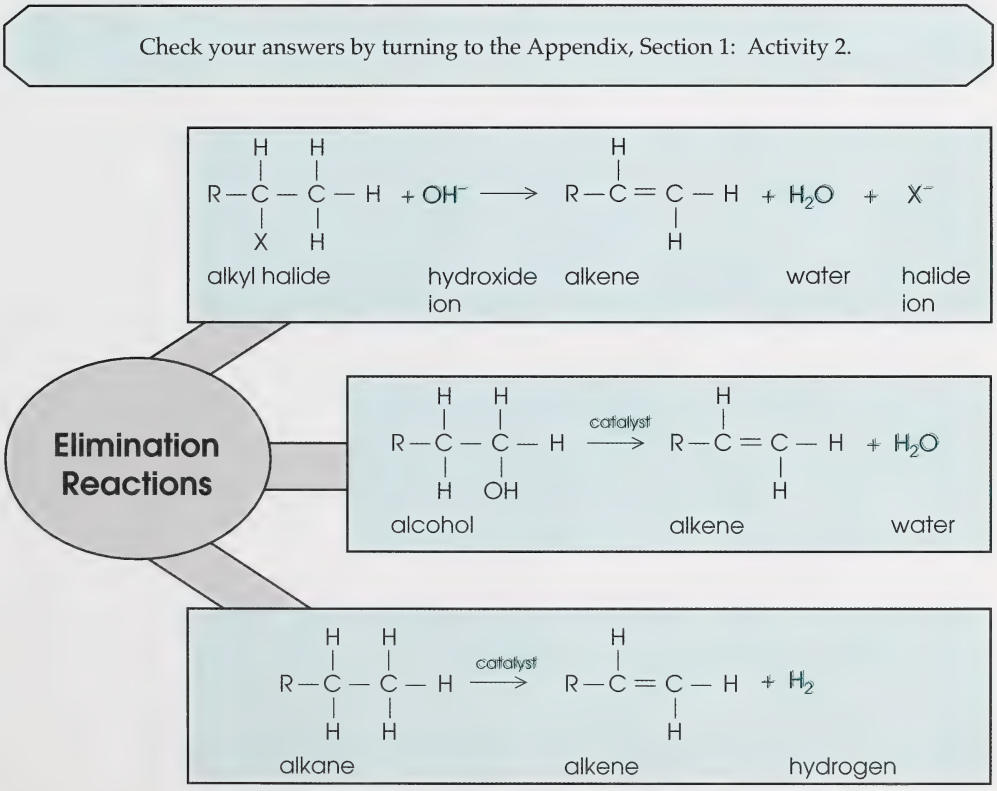
Check your answers by turning to the Appendix, Section 1: Activity 2.

Many of the substances you use each day are complex organic molecules. Most of these substances are probably synthetic. Organic chemists create many materials starting with simple compounds such as ethene or ethane.

You have looked at three types of reactions that are used in constructing simple and complex organic molecules – substitution, addition, and elimination. To gain a basic understanding of synthesizing organic molecules, use your model kit to construct the molecules in the reactions required for the next question.

15. Write possible reactions to perform the following overall change: ethane → ethanol. Write the condensed structural formulas for all organic compounds in each step you have chosen. Indicate what type of reaction you are using for each step and explain any possible problems with your proposed mechanism.

Check your answers by turning to the Appendix, Section 1: Activity 2.



In this activity you looked at organic reactions that are important in the petroleum and produce industries. In the next activity you will look at another reaction type and this reaction's more personal influences on you.

ACTIVITY

3 Esterification

Before you begin this activity, find a wrapper from your favourite candy or packaging from your favourite junk food. Read the list of ingredients. You probably read the words, "contains natural and artificial flavours." Have you ever wondered what the natural and artificial flavours are? For example, the flavouring *isoamyl acetate* listed on the label of a banana candy belongs to the organic family of compounds called esters. Esters are responsible for many artificial flavours and odours. Esters are also responsible for the natural flavours and odours in many fruits and flowers.

Nelson CHEMISTRY

In Module 6 you learned how to name esters; in this activity you will learn how esters are formed. Esters play many important roles. The following investigation from page 265 of your textbook will introduce you to some simple esters and their uses.

Investigation 9.4: Synthesizing an Ester

PATHWAYS

If you have access to laboratory facilities, do Part A.
If you do not have access to laboratory facilities, do Part B.

Part A

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Carefully follow the directions given for the investigation. Pay special attention to the required components, safety aspects, and applied science skills. Note the cautions listed in the margin on page 265.

Caution

1. Complete the evidence for the investigation by recording your observations in a table having the following header:

Ester Formed	Structural Diagram of Reactants	Aroma

Answer the analysis questions that appear after Part B.

End of Part A

Part B

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Caution

Read through Investigation 9.4: Synthesizing an Ester. Pay special attention to the required components, safety aspects, and applied science skills. Note the cautions listed in the margin on page 265.

2. Construct an evidence table with the given header. Obtain the information to fill in your table from the Appendix, Section 1: Activity 3, question 1.

Ester Formed	Structural Diagram of Reactants	Aroma

End of Part B

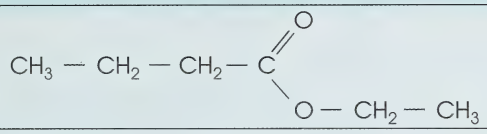
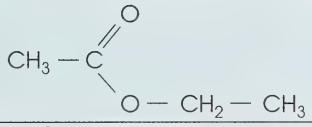
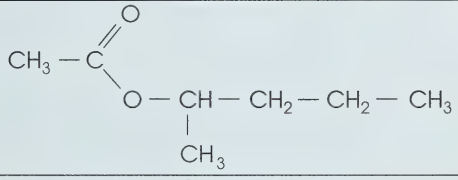
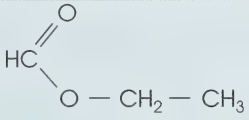
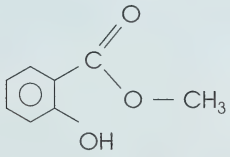
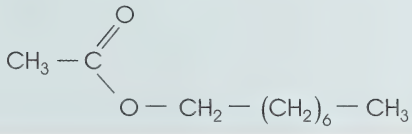
Structural Diagrams of Esters	Aroma
	pineapple
	nail polish remover
	banana
	rum
	wintergreen
	orange

FIGURE 7.5: Esters and Aromas

Analysis

3. What possible uses can you think of for each of the esters that were formed in your investigation? (Your nose will help you.)

4. a. With the data you have obtained, use Figure 7.5: Esters and Aromas for identifying the two esters you have made.

   b. Write an equation for the two reactions that occurred.

5. What molecule is removed to form an ester?

Check your answers by turning to the Appendix, Section 1: Activity 3.

Nelson CHEMISTRY

Read the section Organic Reactions of Carboxylic Acids on page 264 of your textbook for a brief explanation of the **esterification** process.

6. a. Write the general structural diagram for an ester. Label the ester linkage (bond).

   b. What is the difference between esters that creates the various flavours and aromas?

7. Provide an example of a reaction forming an ester that you have not looked at in the preceding investigation or seen in the textbook.

8. If the same esters for aroma and flavour are found in both plants and manufactured foods, what is the difference between natural and artificial esters?

esterification – the production of an ester linkage by reacting a carboxylic acid with an alcohol

Check your answers by turning to the Appendix, Section 1: Activity 3.

Saponification

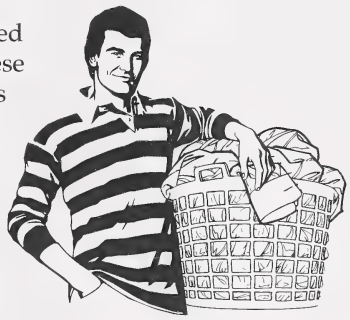
Have you ever bitten into your hamburger and had ketchup, mustard, relish, and beef juices drip onto your favourite shirt or pair of jeans? How do you wash out these stains?

9. Would water alone do a good job of cleaning your clothes?

10. What do you have to add to water to clean your clothes?

saponification – the production of soaps from the breakdown of esters

Soaps and detergents are organic molecules that are formed by breaking esters in a process called **saponification**. These organic molecules help water remove oily dirt from hands and clothes by using their unique molecular structure to dissolve grease (oils and fats) in the water.



In the next investigation, you will produce your own soap and discover the differences in properties between the starting reactants, fats or oils, and the finished product, soap.

Investigation: Making Soap

PATHWAYS

If you have access to laboratory facilities, do Part A.
If you do not have access to laboratory facilities, do Part B.

Part A

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Caution

Carefully follow the directions given for the investigation. Pay special attention to the required components, safety aspects, and applied science skills.

It is recommended that anyone who does Part A should also do Part B to gain a further understanding of soaps and detergents.

CAUTION: The solution of 3.5 mol/L $NaOH_{(aq)}$ is very caustic. Wear goggles and an apron to protect your eyes and clothing. If you spill any $NaOH_{(aq)}$ on your skin, wash with water immediately.

Materials

- clean fat (beef, pork, or lamb **or** this can be lard from the supermarket)
- 3.5 mol/L $NaOH_{(aq)}$ solution
- 250 mL beaker
- 100 mL graduated cylinder
- glass stirring rod
- 2 milk carton bottoms with 2 cm high walls from 250 mL, 500 mL, or 1 L milk cartons
- hot plate
- thermometer

Procedure

- Measure 50 grams of clean fat and place it in a 250 mL beaker.
- Place the beaker on the hot plate and slowly melt the fat. Stir constantly. (**Note:** A temperature of not more than 50°C is adequate or you may burn the fat.)
- When the fat is a clear liquid, remove the beaker from the heat. Cool until the fat shows resistance to the stirring rod (about 30°C).
- Obtain 50 mL of 3.5 mol/L $NaOH_{(aq)}$ in a graduated cylinder.
- Very slowly and carefully pour the $NaOH_{(aq)}$ into the beaker containing the liquid fat. Stir constantly; rapid stirring may be needed to blend the components. Be careful when stirring – this reaction gives off heat.
- Continue to stir until the mixture has stiffened to a honey-like consistency, about 10-20 minutes.
- Pour the mixture into the milk carton bottoms. Cover the soap and allow it to stand for 24 hours.
- After the 24 hours have passed, peel off the carton.

Note: It is recommended that the soap cures for two to three weeks before it is used.

11. Record your observations from the investigation.

12. Answer the following questions as your analysis.

    a. How did the texture of the soap change over the 24 hours?

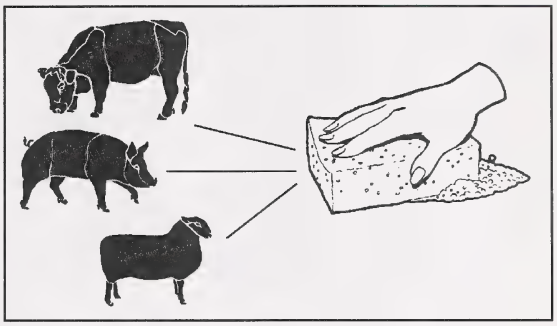
    b. Infer what causes the slippery nature of the soap.

Check your answers by turning to the Appendix, Section 1: Activity 3.

End of Part A

Part B

Have you ever wondered how the excess fat from the meats at your local meat market is disposed of? If you have done the lab in Part A you can make a good guess, but just think about it. Tonnes and tonnes of fat are removed from slaughtered animals every day. Cattle, hogs, and sheep are the common animals butchered in Alberta; where does all the excess fat go? Is there a use for this material?



Fats may be used in the production of soaps and detergents. The following diagram illustrates the cleansing action of soaps and detergents.

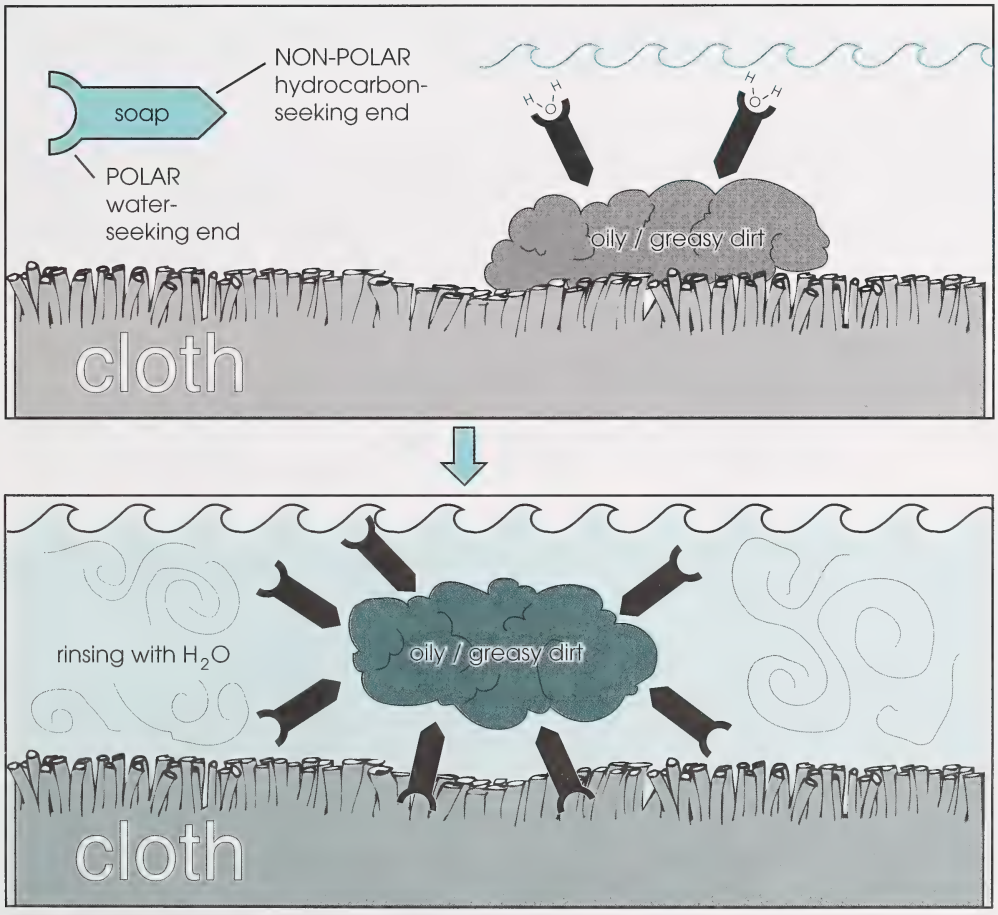
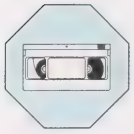


FIGURE 7.6: Cleansing Action of Soaps and Detergents



View the video segment No. 2, Soaps, from the *Organic Chemistry 2 Series* (TVO/ACCESS Network) and answer the following questions to learn more about soaps and detergents. Preview the questions before watching the video.

13. Why does a stain like "ring-around-the-collar" not dissolve easily in water?

14. What material is used to make soap?

15. Name the two types of molecules that make up a fat or oil. Provide structural formulas.

16. Describe how a soap molecule is formed. Illustrate the process using structural formulas.

17. Explain how a soap molecule dissolves grease stains. Refer to Figure 7.6 for help in your explanation.

Check your answers by turning to the Appendix, Section 1: Activity 3.

End of Part B

This activity has provided you with a brief look at esterification and saponification and their applications. The next section will help you learn about a final reaction type, polymerization – how substances such as plastic, polyester, and Teflon® are formed. You will also look at possible careers related to organic chemistry.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

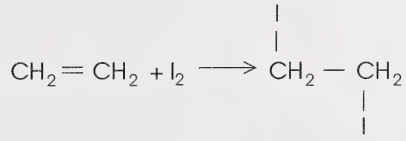
Draw six boxes and label each with the following headings. Leave enough space under each heading for the required information.

Reaction Category:
Reaction Equation(s):
Reason(s):

Label each box with one of the following reaction categories:

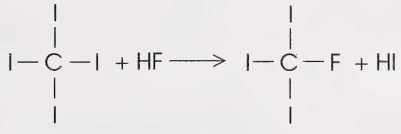
- Substitution
- Addition
- Elimination
- Hydrocarbon Combustion, Cracking, and Reforming
- Esterification
- Saponification

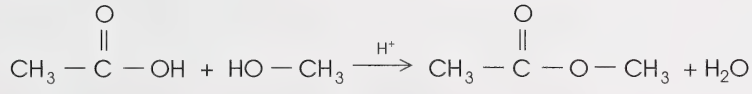
Group the following reaction equations into their appropriate boxes. Give your reasons for placing the equations in the various reaction categories.

a. 

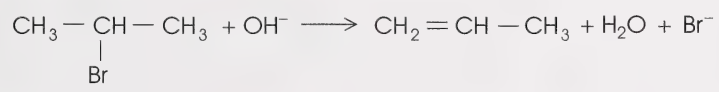
b. $C_9H_{20} + 14\,O_2 \longrightarrow 9\,CO_2 + 10\,H_2O$ + energy

c. large alkanes + $H_2 \xrightarrow[\text{heat}]{\text{catalyst}}$ smaller alkanes

d. 

e. 

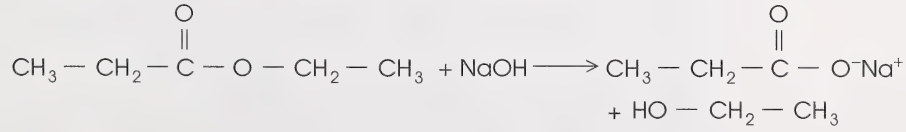
f. $CH_2 = CH_2 + HF \longrightarrow CH_3 - CH_2 - F$

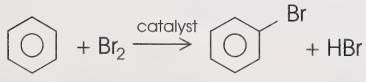
g. 

h. $CH_3 - CH_2 - CH_2 - OH \xrightarrow{H^+} CH_3 - CH = CH_2 + H_2O$

i. $CH_3 - CH_3 \xrightarrow[\text{heat}]{\text{catalyst}} CH_2 = CH_2 + H_2$

j. $CH_2 = CH_2 + H_2O\ (HOH) \xrightarrow{H^+} CH_3 - CH_2 - OH$

k. 

l. 

m. small alkanes $\xrightarrow{\text{catalyst}}$ large, branched alkanes + H_2

n. $CH_3-C\equiv CH + 2\,H_2 \xrightarrow[\text{heat}]{\text{catalyst}} CH_3-CH_2-CH_3$

Check your answers by turning to the Appendix, Section 1: Extra Help.

Enrichment

Complete **one** of the following.

Nelson CHEMISTRY

1. Read the article, "Perspectives on the Use of Fossil Fuels" on page 256 of your textbook. Briefly comment on the types of possible energy alternatives that could reduce the consumption of fossil fuels. If Canada were to reduce its consumption of fossil fuels, how would this affect the economy of the country?

2. If you have access to the video, *Petroleum: River of Energy* (ACCESS Network, 1989), view the tape to gain an overview of the oil and gas industry and its history. Write a brief report highlighting the main aspects of the video. Illustrate how the demands of society and the development of resources are interconnected.

3. Visit your local library to research and prepare a brief report on carbon bonding. How does this information fit into the observation that multiple bonds are more reactive than single bonds (e.g., addition reactions are faster than substitution reactions)?

Check your answers by turning to the Appendix, Section 1: Enrichment.

PHOTO SEARCH LTD.

Conclusion

In this section you have examined a number of simple organic reactions. What you should realize is that these reactions are only steps used to create organic molecules that can be very complex.

The next section looks at one more reaction type, polymerization, and how this process plays a very large role in your life. You will examine some industrial uses of organic chemistry and associated careers. This will help you decide whether or not the use of organic compounds is having a positive or negative impact on your environment.

PHOTO SEARCH LTD.

Assignment Booklet

ASSIGNMENT

Turn to Assignment Booklet 7A and do the assignment for Section 1.

SECTION 2

Polymers and Applications

By now you probably realize that you depend on organic chemistry for a large number of everyday materials. What would your life be like if there were no organic products? Besides not having articles such as most flavouring compounds, perfumes, and cosmetics, another important class of organic compounds would be lost as well. You wouldn't have cassette or compact disc players, at least not ones that would be lightweight. No nylon backpacks, tents, or sleeping bags. No polyester, Dacron®, or rayon.

Into what class of compounds do these products fit? This section will introduce you to an important class of organic molecules called polymers. You will discover how polymers are formed and explore the wide variety of polymers that exist in both living and nonliving systems. You will also discover various careers that have developed in the ever-expanding polymer industry.

ACTIVITY 1

Polymerization

Have you ever heard of Teflon®? What about nylon or acrylic fibres? Why would these materials be mentioned in the same paragraph? All three of these materials are **polymers**.

polymers – large molecules made up of repeating similar subunits called monomers bonded together

1. Look around your room and try to identify five things that you think are made from polymers.

Check your answers by turning to the Appendix, Section 2: Activity 1.

Nelson CHEMISTRY

Now that you have identified a few things that are polymers, ask yourself, "What exactly is a polymer?" To answer your question, read the paragraph entitled Polymers on page 270 of your textbook.

2. Describe each of the following statements as being true or false. If you decide that a statement is false, rewrite the statement to be true.

   a. Polymers are materials with molecules made up of many similar small molecules bound together in a type of chain formation.

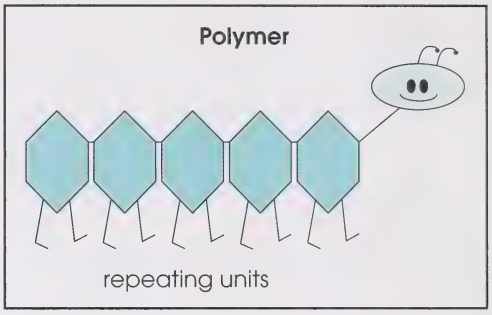
b. These small molecules are called manners.

c. Polymers are formed by a process called polymerization.

d. Polymers do not occur in nature and have been synthesized by chemists for the past three hundred years.

Check your answers by turning to the Appendix, Section 2: Activity 1.

Have you ever taken dandelions and removed the flowers to make a chain out of the stems? This is very much like a polymer – a chain of repeating units. Polymers play an integral part in the function of life systems and have revolutionized the way society functions.

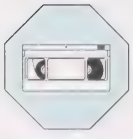


PATHWAYS

If you have access to the video *Organic Chemistry 1 Series*, segment number 5, Polyethylene, do Part A.

If you do not have access to the video, do Part B. It is recommended that you do both parts, if possible.

Part A



Find and view the segment Polyethylene from the *Organic Chemistry 1 Series*. This video outlines one type of polymerization process and gives you an idea of the many applications possible for polymers.

You may wish to preview the questions before viewing the video.

polymerization – the process of making polymers

3. a. How was the first synthetic polymer discovered?

   b. What immediate effect on society did the discovery of this polymer have?

4. a. What type of plastic is produced in the greatest amounts today?

   b. How is this type of plastic used?

5. How is the great variety of plastic products possible?

6. a. What are the repeating units of a polymer called?

   b. Briefly describe how the units of a polymer get tied together.

7. a. What is the process called that converts ethene (ethylene) to polyethene (polyethylene)?

   b. What three conditions or factors are necessary for the polymerization of ethene to occur?

Low Density Polymers

garbage bags, squeeze bottles, food containers

High Density Polymers

structured materials, building blocks

8. Create a two-column table similar to the following:

Low Density Polymers	High Density Polymers

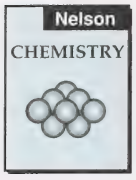
Place the following terms or descriptions in the appropriate column.

- high pressure (1500 atmospheres)
- linear uniform molecules tightly packed together
- flexible plastics
- lower pressures
- benzoyl peroxide catalyst
- hard plastics
- branched chains loosely packed
- chromium oxide catalyst

Check your answers by turning to the Appendix, Section 2: Activity 1.

End of Part A

Part B



Read the section on Addition Polymers on pages 270 and 271 of your textbook. This section gives you a brief description and several examples of one type of polymerization. Study the margin description and graphics as well.

9. Give an example of one organic compound that can undergo addition polymerization.

10. For which products can polyethylene (polyethene) be used?

11. What are the repeating units of a polymer called?

12. a. Describe briefly how addition polymers are formed.

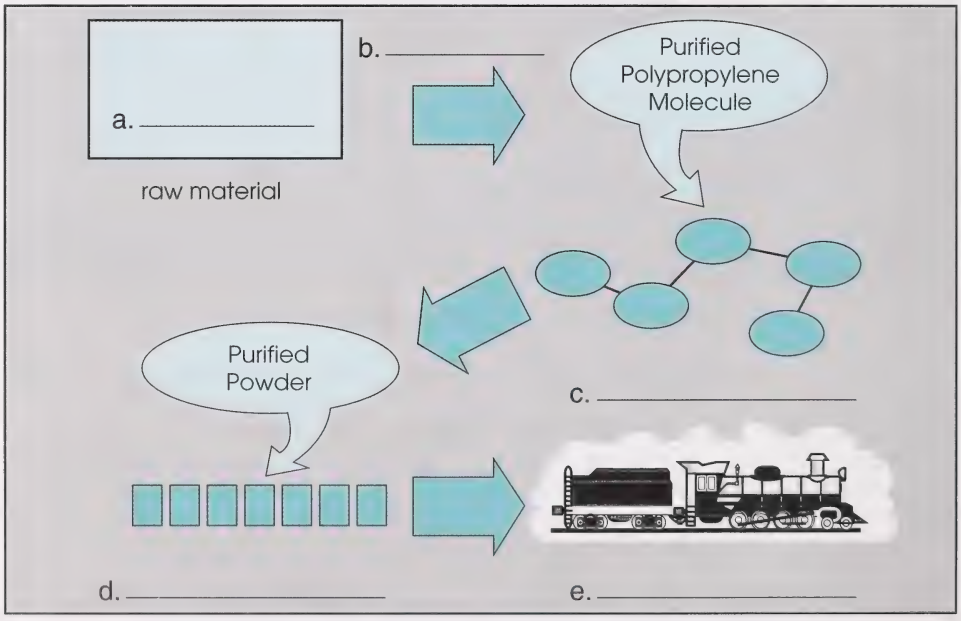
    b. How many products are formed in addition polymerization?

13. How can the properties of one polymer be made different from another?

14. a. Give three examples of commercial products that are addition polymers.

    b. Give two examples of natural compounds that are polymers.

15. Describe the steps that trace the production of polypropylene.



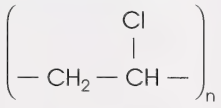
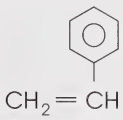
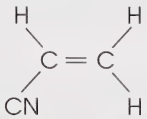
Check your answers by turning to the Appendix, Section 2: Activity 1.

End of Part B

addition polymerization – a reaction in which unsaturated monomers combine (by addition) with each other to form a polymer (as the only product)

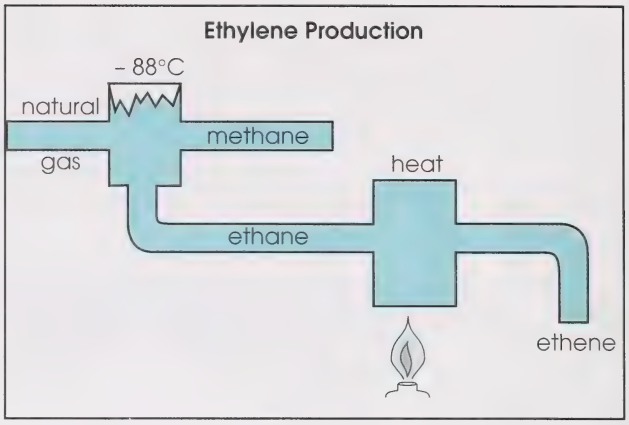
As you have discovered, **addition polymerization** makes use of monomers such as ethene (ethylene). By varying the different functional groups attached to the ethene molecule, many forms of polymers can be made.

16. Fill in the following chart with the missing monomer or polymer molecule structure to complete the comparison of ethene and its analogues (compounds similar to ethene). Note the various applications that are possible by altering ethene.

Monomer Structural Formula	Polymer Molecule Structural Formula	Applications
chloroethene _____	polyvinyl chloride 	vinyl tile and plumbing drain pipe
ethene _____	polyethylene _____	plastic bottles and containers, plastic bags
tetrafluoroethene _____	polytetrafluoroethene (Teflon®) _____	gasket material, seal for metal pipe joints, coats cooking surfaces
vinyl benzene 	polystyrene (Styrofoam) _____	floating devices, house insulation, insulated food containers
acrylonitrile 	polyacrylonitrile (acrylic) _____	socks, sweaters (looks and feels like wool)
1,1-dichloroethene (vinylidene chloride) _____	polyvinylidene chloride _____	plastic food wrapping

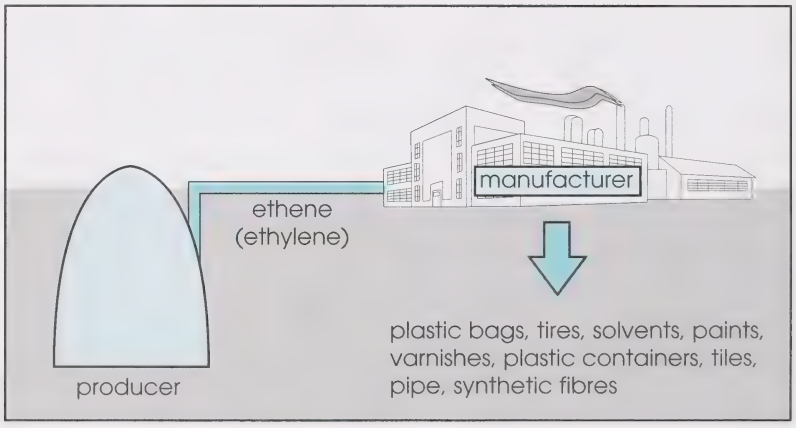
Check your answers by turning to the Appendix, Section 2: Activity 1.

The production of ethylene (ethene) is an important industry in Alberta. Ethane gas is separated from natural gas by low temperature fractionation at plants in places such as Edmonton, Empress, and Cochrane. The ethane is piped to a plant in Joffre, east of Red Deer, where it is converted into ethene by using heat.



Ethene is then piped to Fort Saskatchewan where it is used by various companies to make analogues of ethene (for example, vinyl chloride). Ethene and these analogues are then used to create marketable polymer products.

Not all the ethene or ethene analogues remain in Alberta. Much of the ethene and its analogues are piped to Ontario to be used in additional manufacturing processes.



condensation polymerization – a process that forms a polymer and a small molecule such as water as the products

You should be familiar with the term *polyester*. You may even be wearing some at this very minute. How is polyester produced? Did you know that your body uses a similar process to produce proteins?

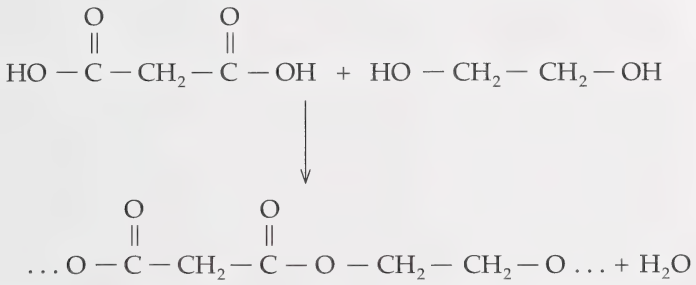
The process just referred to is called condensation polymerization. To discover more about this process, read page 272 in your textbook.

17. Identify each of the following statements as true or false. For each false statement, rewrite the statement to be true.

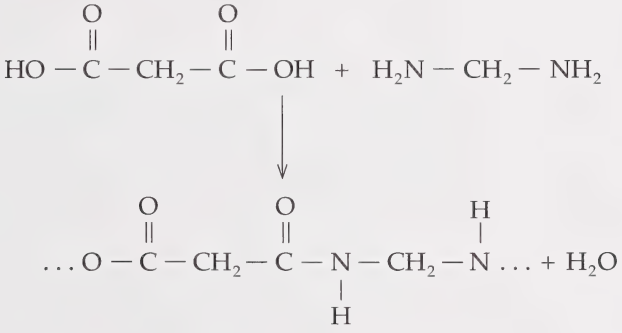
    a. Condensation polymerization does not require any functional groups on the monomers.

    b. In condensation polymerization there are two products formed, the polymer and some small type of molecule such as H_2O, NH_3, or HCl.

    c. A polyester involves the reaction between a bifunctional alcohol and a bifunctional carboxylic acid.



    d. A polyamide involves the reaction between a bifunctional carboxylic acid and a bifunctional amine.



18. Define the term *bifunctional*.

19. List two common names each for types of polyester and polyamides.

Check your answers by turning to the Appendix, Section 2: Activity 1.

Figure 7.7 summarizes the process of condensation polymerization.

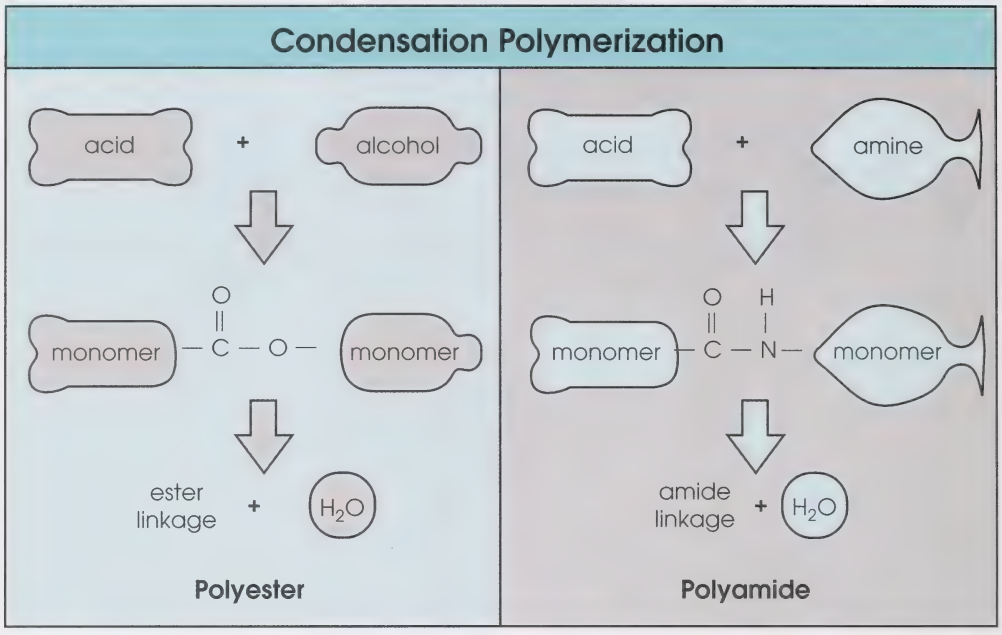


FIGURE 7.7: Condensation Polymerization

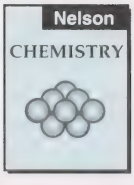
Your model kit can help you to visualize what these polymer molecules look like. Using your model kit, construct two molecules of 2-hydroxyethanoic acid,

$$HO - CH_2 - \overset{\overset{O}{\|}}{C} - OH$$

20. a. Is 2-hydroxyethanoic acid bifunctional?

    b. What are the functional groups?

    c. How does 2-hydroxyethanoic acid differ from the monomers illustrated on page 272 of your textbook?



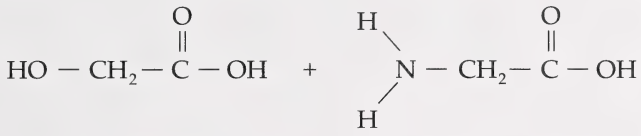
21. Based on the knowledge you have gained about condensation polymerization, create a polymer unit from the two acid molecules you made.

    a. Draw the structural diagrams for the products you have made.

    b. What molecule did you produce besides the polymer unit?

    c. What general type of condensation polymer have you made? Explain.

Take your polymer apart and recreate the two separate 2-hydroxyethanoic acid molecules with which you started. On one molecule, replace the hydroxyl group, — OH, with an amine group. You will end up with the following:



2-hydroxyethanoic acid 2-aminoethanoic acid

Now, make a polymer unit from the two molecules you have.

22. a. Draw the structural diagrams of the products from the preceding polymerization.

    b. What type of condensation polymer was formed this time? Explain.

    c. What same molecule was formed as in the first polymerization you performed?

Check your answers by turning to the Appendix, Section 2: Activity 1.

From your reading so far you learned that polymers are very useful materials. Up until now, you have mainly been studying synthetic polymers. However, many polymers are also found in nature.

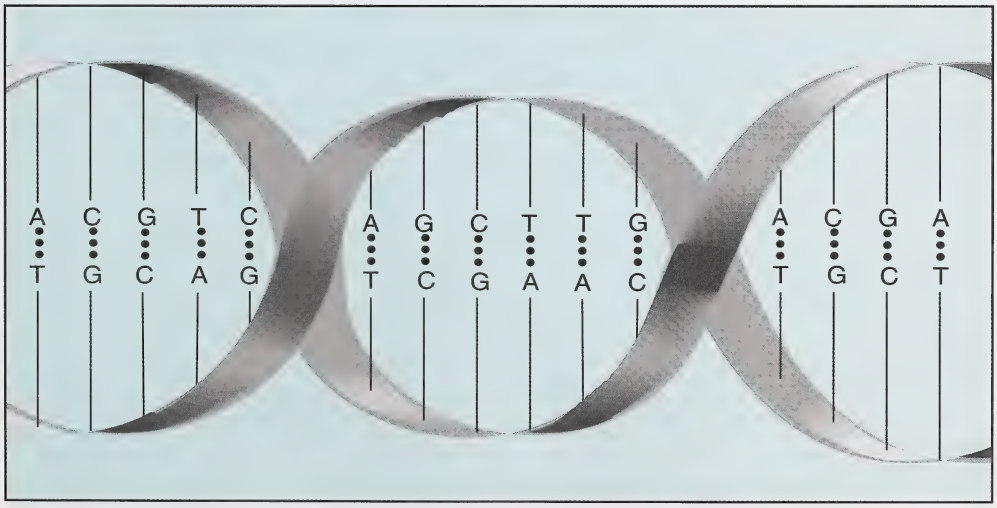
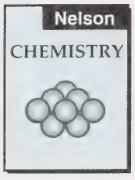


FIGURE 7.8: DNA – A Natural Polymer

You may have heard of DNA (deoxyribonucleic acid) as the substance that makes you like your ancestors, but did you know that DNA was a polymer? You may be more familiar with a different natural polymer – rubber.



There are many important natural polymers. Read about natural polymers on page 274 of your textbook to learn about several polymers without which you could not survive.

23. Complete the following statements by filling in the blanks.

    a. Two example classes of natural polymers are _____ and _____.

    b. Proteins are made up of monomers called _____ _____.

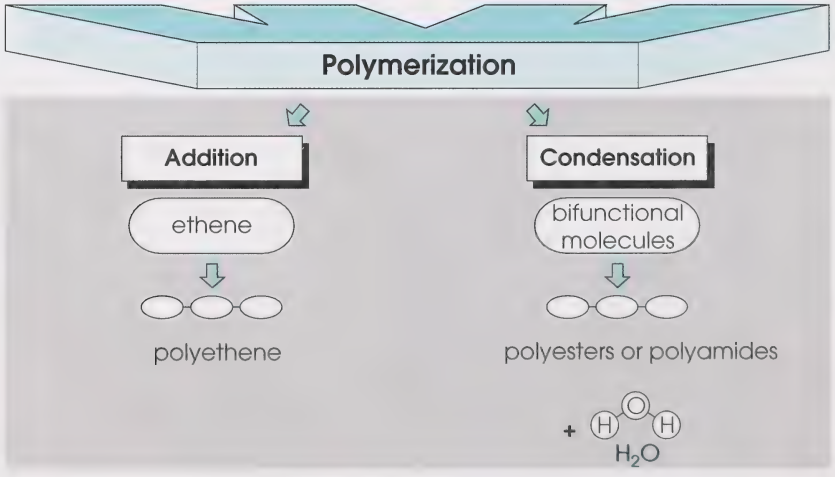
    c. Amino acids are bifunctional monomers because they have an _____ _____ ($-NH_2$) at one end and a _____ _____ ($-COOH$) at the other end.

    d. The type of polymerization used to form a protein is called _____ _____.

    e. The monomer units of carbohydrates are _____ _____.

    f. Two examples of carbohydrates are _____ and _____.

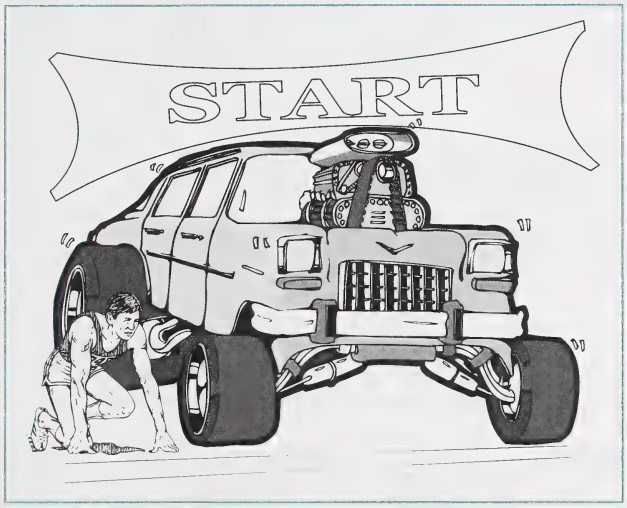
Check your answers by turning to the Appendix, Section 2: Activity 1.



You have been introduced to the concept of polymerization in this activity and some important polymers in industry and in living organisms. In the next activity you will compare polymerization reactions that occur in living and nonliving systems.

ACTIVITY

2 Reactions and Systems



Have you ever tried to outrace a car? Perhaps only a comic book hero has this ability. When you think about it, though, you are very similar to an automobile in the way you obtain your energy. In Activity 2 of Section 1 you learned that your body, a living system, burns **carbohydrates**, a close relative of the hydrocarbon to obtain energy. An automobile engine, a nonliving system, burns hydrocarbons.

carbohydrates – polymers classified as sugars, containing compounds such as glucose or fructose

The basic reactions for the two systems can be represented as follows.

Your Body

$$C_6H_{12}O_{6(s)} + 9\ O_{2(g)} \rightarrow 6\ CO_{2(g)} + 6\ H_2O_{(l)} + \text{energy}$$

glucose

↳ one monomer of a carbohydrate

An Automobile

$$2\ C_8H_{18(l)} + 25\ O_{2(g)} \rightarrow 8\ CO_{2(g)} + 9\ H_2O_{(g)} + \text{energy}$$

octane

↳ one hydrocarbon component of gasoline (complete combustion is assumed)

A major difference between yourself and an automobile engine is the efficiency in obtaining energy. You can compare the two systems to determine which is the more efficient.

1. The following chart illustrates the burning of glucose $(C_6H_{12}O_6)$, a carbohydrate, in your body and octane (C_8H_{18}), a hydrocarbon, in an automobile engine. Determine the amount of energy that is obtained by each system and the efficiency of each system (the percent of energy obtained from the total energy available in burning the carbohydrate or hydrocarbon).

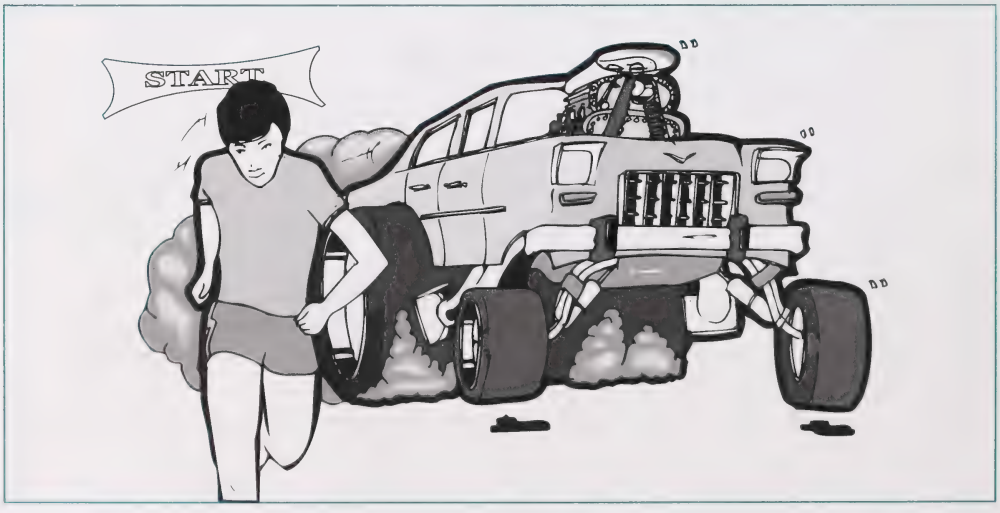
$$\text{Efficiency of a system } (\%) = \frac{\text{energy obtained by system}}{\text{total energy available}} \times 100$$

Molecule	Total Energy Available (kJ/mol)	Energy Lost as Heat (kJ/mol)	Usable Energy in System (kJ/mol)	Efficiency of the System (%)
Glucose	2.80×10^3	1.03×10^3		
Octane	5.07×10^3	3.80×10^3		

2. Which system is more efficient in obtaining energy? Why?

Check your answers by turning to the Appendix, Section 2: Activity 2.

Why is the automobile engine less efficient than your body in obtaining energy? You can look at the conditions in which both of these reactions occur to give you a clue. The following chart illustrates the general conditions that exist for both systems. Use the chart to answer the following questions.



Condition	System	
	Engine	Body
Adds energy to start the reaction	yes	yes
Uses heat to assist the reaction	yes	no
Creates pressure to assist the reaction	yes	no
Uses an enzyme (catalyst) to assist the reaction	no	yes

3. a. What conditions in the automobile engine differ from the body in obtaining energy?

   b. Which of these conditions aid the automobile engine in obtaining energy?

   c. Which of these conditions aid the body in obtaining energy?

Check your answers by turning to the Appendix, Section 2: Activity 2.

enzyme – a protein catalyst

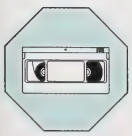
What is an **enzyme**? In Activity 1 you looked at natural polymers called proteins. Enzymes are proteins that lower the activation energy in a reaction; in other words, they speed up the reaction.

PATHWAYS

If you have access to the video segment, Harvest of Enzymes, from the *Organic Chemistry 1 Series*, do Part A. If you do not have access to the video, do Part B.

It is recommended that you do both Parts A and B, if possible.

Part A



To discover more about these wonders of nature – enzymes – find and view video segment 6, Harvest of Enzymes, from the *Organic Chemistry 1 Series*.

Answer the following questions as you watch the video. Be sure to preview the questions before you begin viewing.

4. What determines the shape of an enzyme?

5. What is the region of the enzyme called that is involved with a reaction?

6. Why are enzymes so specific in the reactions they catalyse?

7. Would a living system (for example, your body) be able to exist without enzymes? Explain.

It is the specific nature of enzymes that increases the efficiency of a living system in obtaining energy from carbohydrates.

Not all nonliving systems have to rely on only temperature and pressure to speed up reactions. Catalysts may also be used. Enzyme catalysts have become very attractive for use by industry.

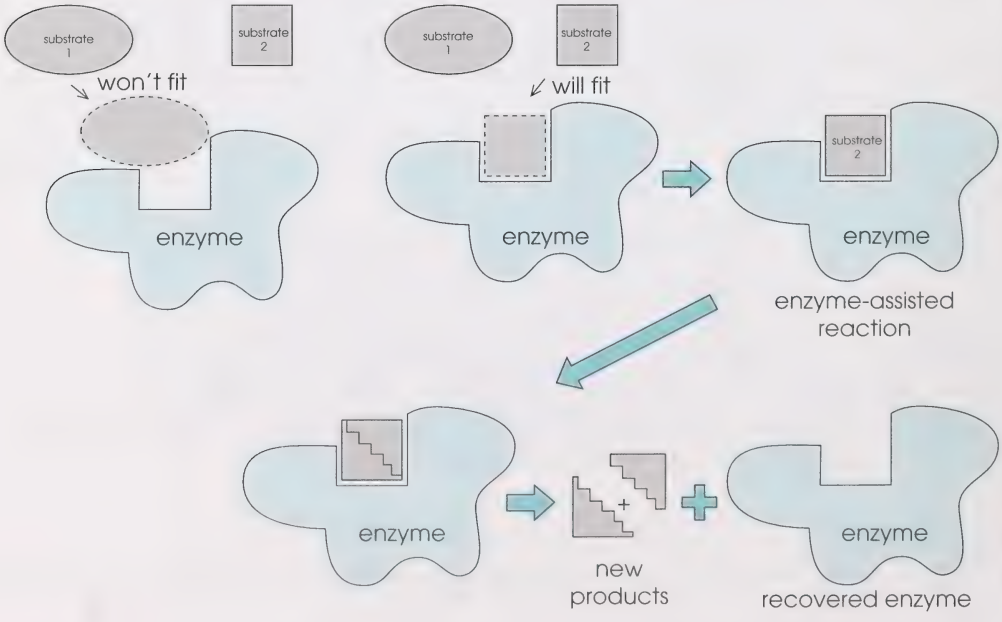
8. Name three applications for using enzymes in industry that are mentioned in the video, Harvest of Enzymes.

Check your answers by turning to the Appendix, Section 2: Activity 2.

End of Part A

Part B

The enzymes in your body have just catalysed a few thousand reactions in the last second without you even knowing it. Enzymes are designed to speed up specific reactions in your body – one enzyme for one process. How are they so specific?



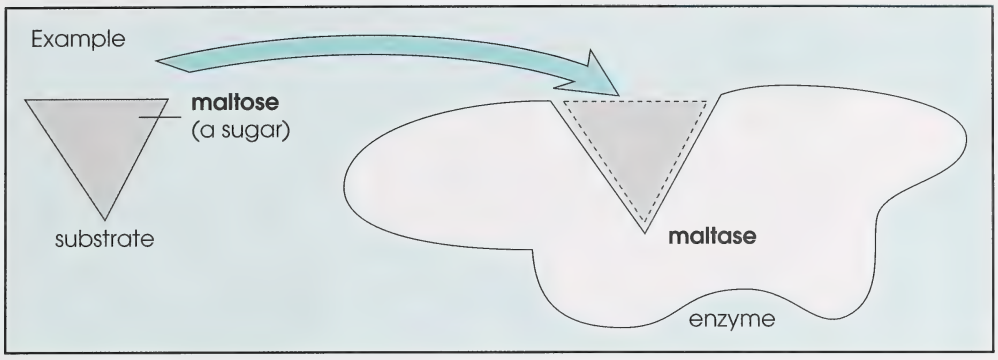


FIGURE 7.9: The Close Fit of an Enzyme and Substrate

substrate – the reactant of an enzyme-catalysed reaction

The long protein chains of enzymes are held together in their substrate-specific shape by intermolecular bonds. Since enzymes only speed up reactions for specific substrates the enzymes are named after the substrate.

Enzymes are not only used in your body. Enzymes are also used commercially in bakeries and breweries and in manufacturing soaps and detergents.

You will find that the most abundant sources of commercial enzymes are microorganisms such as bacteria. Enzymes are crucial to your well-being. Without them, you would not function.

9. What is the purpose of an enzyme?

10. How do enzymes know which reaction to catalyse?

11. When an enzyme catalyses a reaction, is it used up? Explain.

12. How do enzymes achieve their substrate-specific shape?

13. How are enzymes used in industry?

Check your answers by turning to the Appendix, Section 2: Activity 2.

End of Part B

In this activity you have compared living and nonliving systems that obtain energy. You have seen how nonliving systems rely on altering conditions such as pressure and temperature to speed up reactions, while living systems must rely on enzymes.

In the next activity you will have the opportunity to look at organic chemistry as a possible avenue of employment and examine the positive and negative effects of some of the products of organic chemistry.

ACTIVITY

3 Careers and Applications

You have been studying many organic compounds – their involvement in reactions and their applications. Have you ever wondered what it would be like having a job related to some of the materials you have been studying? What career opportunities exist that are related to organic chemistry?

Nelson CHEMISTRY

One career involves a recent opportunity that is being filled by innovative individuals. Read page 273 in your textbook to see how a plastics technologist has achieved success in a growing industry.

1. When you talk about plastics, to what types of materials are you making reference?

2. The recovery of plastics has many problems that must be overcome to obtain a reusable material. Briefly explain the recovery process of PET and comment on why you think each step must be taken.

3. What kind of background and motivation would you need to become a plastics technologist?

Check your answers by turning to the Appendix, Section 2: Activity 3.

AOSTRA

Nelson CHEMISTRY

Many career opportunities involve working with specific organic molecules. Improving the understanding of these organic molecules usually leads to improvements in society. One example is described in the article about Raymond Lemieux on page 241 of your textbook.

4. The work of Raymond Lemieux dealt with saccharides (sugars). What were the benefits to society when Dr. Lemieux synthesized a trisaccharide? What would be the detrimental effects if Dr. Lemieux had not been successful in his work?

5. What possible lesson can be learned from Dr. Lemieux's success as a chemist, even though his initial dream was a hockey career?

Check your answers by turning to the Appendix, Section 2: Activity 3.

You have already discovered the world of enzymes and its many crucial functions, but how did much of the groundbreaking work on enzymes come about?

Nelson CHEMISTRY

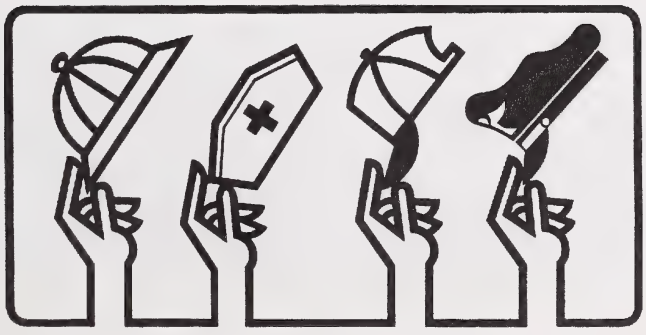
Read the profile on the Canadian doctor and biochemist, Maud Menten, on page 276 of your textbook to discover a brilliant and diverse personality.

6. Briefly describe the theory of "enzyme complex" action proposed by Maud Menten and Leonor Michaelis.

7. How do you think understanding the way one enzyme functions influences the understanding of how other enzymes function?

8. How does Maud Menten reflect the old saying, "If you want something done, give it to a busy person"?

Check your answers by turning to the Appendix, Section 2: Activity 3.



There are many careers that involve organic chemistry. Figure 7.10 illustrates only a few of the many careers that are related to organic chemistry.

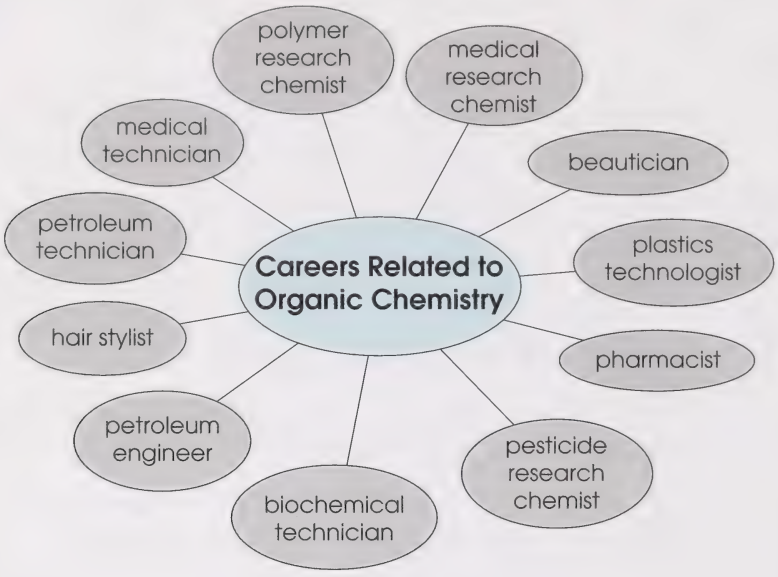


FIGURE 7.10: Careers in Organic Chemistry

Society has a large demand for products of organic chemistry. You will see this demand increase the employment opportunities in a number of areas. What are the future implications on the demand for organic chemical products based on the way you live and the environment in which you live?

Nelson CHEMISTRY

In Module 1 you looked at an organic molecule that has caused severe environmental reactions with its use, DDT. From the article on page 130 of your textbook you learned that dichlorodiphenyltrichloroethane, DDT, was widely used as an insecticide for twenty years in North America. Though effective as an insecticide, DDT concentrations were magnified up the food chain. This resulted in a dramatic decrease in the populations of predatory birds.

insecticide – a substance that kills insects

Society must often make tough decisions when dealing with the balance between the good and bad effects of substances such as insecticides or other organic molecules. There are many positive and negative aspects to using organic molecules. Two important issues that have arisen from the use of organic molecules are waste management and the loss of the ozone layer. Over the past few decades society has turned to the convenience of throw-away products.

9. If you were to use every product only once, how much garbage (in kilograms) do you think could be generated by yourself in one day? Make a guess.

Obviously you do not throw everything away after one use. There would be many good appliances, cars, and clothes in the landfill if you did.

10. To give you a good idea of how much garbage you generate, keep a list of everything you throw away for one day. Over the next 24 hours save everything in a container so you can determine just how much garbage you generate. How much garbage do you generate? (Try weighing your refuse.)

Check your answers by turning to the Appendix, Section 2: Activity 3.

You may also wish to evaluate the amount of garbage your family generates for one day. You have probably discovered that the amount of garbage you or your family create in one day is not very great, but multiply the amount by 365 to estimate a year's worth of garbage. Then multiply this number by the number of households in your town or city (divide the town's population by about five people per family for a good estimate) and you will have a very large quantity of refuse. Do not forget that industry also creates its own larger share of garbage.

Where do you put all the waste? Do you think there will ever be a problem finding the area required for landfill sites?

PHOTO SEARCH LTD.

biodegradable – having the ability to readily decompose in nature

You may suggest that much of this waste will degrade. There are arguments to suggest that even biodegradable waste takes a long time to decompose, but what about the material that does not degrade? In Activity 1 of this section you looked at very useful products from the process of polymerization – plastics. Plastics are widely used because of their resistance to chemical change and decomposition.

11. a. Look at the garbage you generated in one day. How much of this refuse was composed of plastic products?

    b. Make a suggestion concerning what you could do with the plastic waste.

Check your answers by turning to the Appendix, Section 2: Activity 3.

Throughout your life you will have to make decisions about whether or not to do certain tasks or use certain products. Your decision will be based on your perception of the risks involved and the benefits of the task or product.

In Module 1, you completed a risk-benefit analysis based on an article about mercury and its risks and benefits. Now, you will do another analysis.

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☑ F. Evaluating

12. Read the following article, *"Recycling leads to fenceposts."* Make a two-column table, listing the benefits you perceive in one column, and the risks you perceive in the other column.

Recycling leads to fenceposts

Pesticide holders put to new use

Dow Jones Service

EDMONTON – A Canadian company has developed a fencepost made of high-density plastic from recycled farm pesticide containers. "They will last for generations," said Harvey Jaehn, president of **Superwood Western Ltd.** of Edmonton.

Although it isn't possible to wash out all the pesticide that has leached into the plastic, the small chemical residue in the posts poses no health threat, according to the University of Guelph toxicology department.

Superwood Western recently completed a test run of 10,000 posts that it sold to the Alberta government for $43,000. It expects to produce 175,000 to 200,000 posts annually after they hit the market this fall.

The plastic "Agriplast" posts will cost about 10 to 20 per cent more than conventional wooden posts, but Mr. Jaehn said buyers will be attracted by their durability.

Discarded chemical containers were a fixture of farmyards and roadside ditches until the early 1980s, when environmental concerns prompted the industry to launch a recycling program.

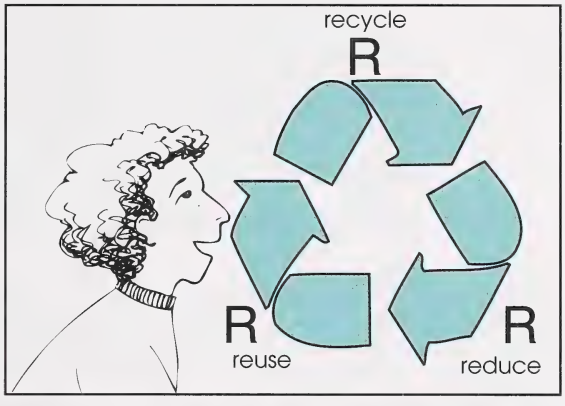
Now roughly 80 per cent of all containers sold in Western Canada are dropped off at more than 500 collection sites across the prairies, according to industry figures.[1]

[1] Reprinted by permission of *The Globe and Mail*, ©1992 Dow Jones & Company, Inc. All Rights Reserved Worldwide.

13. In your opinion, based on your list of benefits and risks, do you think that these fenceposts are beneficial or are good to use? Explain.

Check your answers by turning to the Appendix, Section 2: Activity 3.

Though you may think society is on the right track with recycling plastics, there are many organic molecules that still pose a menacing danger. Contaminated soil from former oil refinery sites, petrochemical plants, and creosote industries have been in the news and will continue to be of concern to you and society in the future.



CITY OF EDMONTON PUBLIC WORKS

The discovery of chlorofluorocarbons, CFCs, have been a boon to society. CFCs are used to create foam and packaging materials; have been used as propellants in aerosol sprays and cleaning agents; and are used as refrigeration fluid in vehicle air conditioning, refrigerators, and freezers.

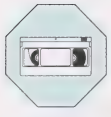
However, as mentioned in Module 6, CFCs are creating problems with the Earth's ozone layer. You have to be very careful when sunbathing or when swimming or when sitting by a pool. The ultraviolet radiation due to the decreasing ozone layer can be quite intense and harmful.

PATHWAYS

If you have access to the video segment Ozone of the *Planet Under Pressure Series*, do Part A. If you do not have access to the video, do Part B.

It is recommended that you do both Parts A and B, if possible.

Part A



Find and view the video segment Ozone from the *Planet Under Pressure Series* (TVO/ACCESS Network). This video will give you some insights into what the ozone layer is and some of the problems it faces. Answer the following questions as you watch the video. Be sure to preview the questions before you begin viewing.

14. a. What technologies were made possible by the magic chemical, the "genie in a bottle", that scientists discovered?

    b. What characteristics did this magic chemical possess?

    c. What effects were foreseen of this chemical on the environment?

15. What was this magic chemical? Give one example and show its structural diagrams.

16. a. When scientists began to worry about the effect of CFCs on the environment, briefly describe their theory about how the CFCs would behave in the environment.

    b. When and where was the scientists' theory confirmed?

    c. Have the effects of the CFCs increased, decreased, or stayed the same since the first detection?

17. a. What possible effects are envisioned if the ozone layer remains depleted?

    b. What are some solutions that are being proposed to stop the CFC problem?

18. What lesson can be learned from the CFC problem?

Check your answers by turning to the Appendix, Section 2: Activity 3.

End of Part A

Part B

CFCs can have chlorine and fluorine in different proportions depending on their particular use or need. As an example, tetrahalogenated methane (methane with four halogen atoms attached), also known as Freon, is used as refrigeration fluid.

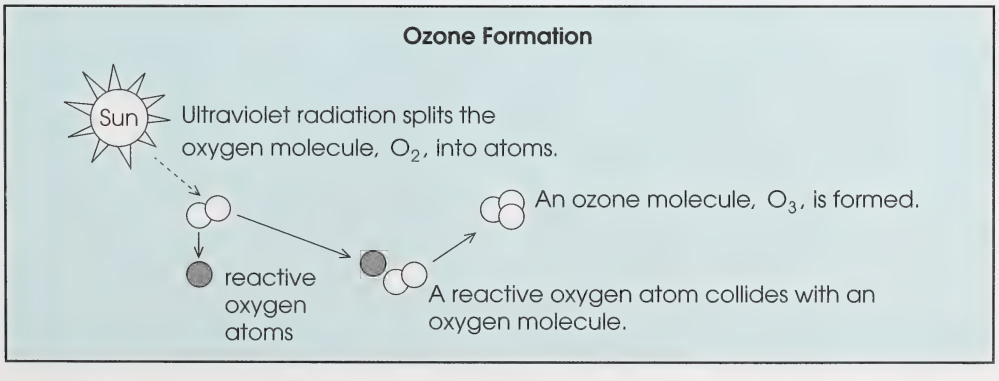
19. Create a chart similar to the following. Complete your chart by writing the IUPAC names for the four Freons shown.

Molecular Formula	Common Name	IUPAC Name
$CFCl_3$	Freon 11	
CF_2Cl_2	Freon 12	
CF_3Cl	Freon 13	
CF_4	Freon 14	

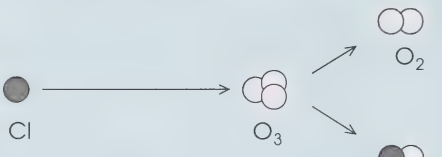
20. What benefits would you lack if there were no refrigeration?

Check your answers by turning to the Appendix, Section 2: Activity 3.

The chlorine atom in CFCs destroys the protective ozone allowing greater levels of ultraviolet radiation to reach the Earth's surface. Ultraviolet (UV) radiation is linked to a number of dangerous situations in human health and the environment.


Ozone Formation
Sun
Ultraviolet radiation splits the oxygen molecule, O_2, into atoms.
An ozone molecule, O_3, is formed.
reactive oxygen atoms
A reactive oxygen atom collides with an oxygen molecule.

Ozone Depletion



Reactive chlorine atoms from CFCs collide with ozone, O_3, which produces O_2 and ClO.

The ClO then reacts with an oxygen atom, producing oxygen gas and a chlorine atom. The chlorine atom can then react with another ozone molecule.

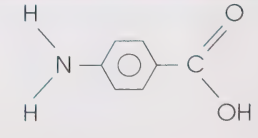
21. Complete the following chart that illustrates potential effects of UV radiation. Indicate what you think the result is of increased UV radiation in each case.

Affected Area	Effect	Result
Eyes	develop cataracts (clouding of the lens)	
Skin	drying and wrinkling, burns, uncontrolled skin cell growth	
Immune system	reduced immune response	
Crops	interference with photosynthesis	
Marine life	reduced growth of phytoplankton	

Check your answers by turning to the Appendix, Section 2: Activity 3.

End of Part B

Many people are working hard to find substitute technology to replace current applications of organic chemistry that are causing problems. Stopping the use of CFC products is one area in which you could make a significant impact on your environment.



PABA: p-aminobenzoic acid

You may find it interesting to know that you use another organic molecule to block UV radiation. PABA, p-aminobenzoic acid, is used in sunscreens to block UV rays.

This activity has given you a brief look at some careers involving organic chemistry and the positive and negative effects of using organic molecules to solve problems. You may have to make some tough choices in the near future to safeguard your health and the environment.

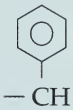
Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

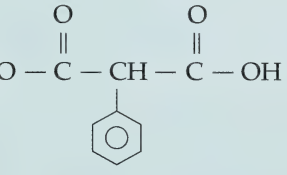
Use the following random list of descriptors and structures for filling in the blanks and squares of the Extra Help questions.

- pressure
- enzymes
- insulation
- skin cancer
- chlorofluorocarbons
- monomers
- temperature
- H_2O
- plastic bags
- polymers
- positive
- addition polymerization
- plastics technologist
- condensation polymerization
- protein
- beautician
- water
- polymerization
- UV radiation
- ozone
- negative

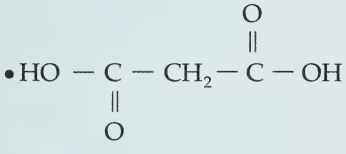


- $H_2N-CH-NH_2$

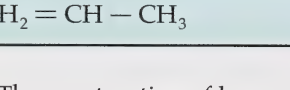
- $HO-CH_2-CH-CH_2-OH$



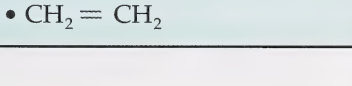
- $HO-C(=O)-CH(C_6H_5)-C(=O)-OH$



- $HO-C(=O)-CH_2-C(=O)-OH$



- $CH_2=CH-CH_3$

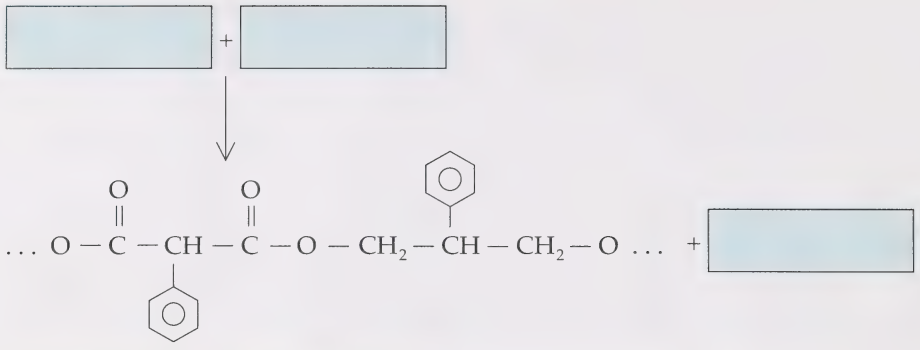


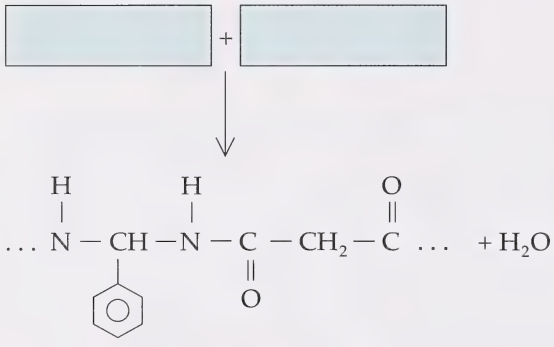
- $CH_2=CH_2$

1. a. The construction of large molecules from smaller repeating molecules is called _____.

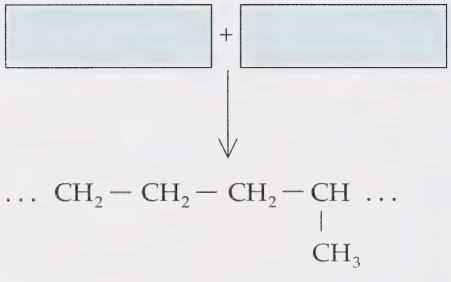
   b. The smaller molecules are called _____.

   c. The large molecules are called _____.

2. 

3. 

4. The polymerization reactions in the preceding questions are examples of _____ _____, because both a polymer and _____ are formed.

5. a. 

   b. The preceding polymerization reaction is an example of _____ _____.

6. Polymers can be used to make _____ and _____.

7. Polymers also occur in nature. An example of a natural polymer is _____.

8. a. To assist a reaction, a nonliving system may use _____ and _____.

   b. To assist a reaction, a living system uses _____.

9. Two careers that are involved with organic chemistry are _____ and _____.

10. Using organic chemistry to solve problems can have both _____ and _____ consequences.

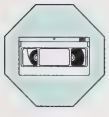
11. An example of a useful group of organic molecules is the _____, but these molecules also may reduce the _____ in the atmosphere, allowing increased levels of _____ to reach the Earth's surface.

12. Ultraviolet radiation can cause _____ _____.

Check your answers by turning to the Appendix, Section 2: Extra Help.

Enrichment

Complete **one** of the following.



1. If you have access to the challenging environmental game NIMBY (Alberta Department of Environment) and a few friends who are willing to help you for a few hours, try playing the game and learn about the decisions that are required to select and maintain a landfill site. This game can be played on several levels and you will find it to be a definite challenge.

2. If you have access to the video segment Cosmetics from the *Organic Chemistry 2 Series*, view the tape and write a brief summary of the procedures and decisions required to produce lipstick.

3. Visit your local library and research the topic synthetic fibres. Write a brief report on the production of synthetic fibres and their applications.

Check your answers by turning to the Appendix, Section 2: Enrichment.

Conclusion

In this section you have looked at the process of polymerization, some career options involving organic chemistry, and how organic chemicals can have both positive and negative effects. It is important for you to keep informed on new developments to ensure that you can make knowledgeable decisions on matters of the benefits of organic materials as well as the risks.

Assignment Booklet

ASSIGNMENT

Turn to Assignment Booklet 7B and do the assignment for Section 2.

MODULE SUMMARY

Your learning has made you more aware of what can be involved in an organic reaction. You probably have a greater appreciation of the extensive use of organic chemistry in society and the numerous careers that are related to organic chemistry. Finally, you have seen how solving problems with organic chemistry can sometimes lead to negative reactions and problems of greater significance in the environment.

COURSE SURVEY FOR CHEMISTRY 20
(© 1993, 2001)

After you have completed the assignments in this course, please fill out this questionnaire and mail it to the address given on the last page. This course is designed in a new distance learning format, so we are interested in your responses. Your constructive comments will be greatly appreciated, as future course revisions can then incorporate any necessary improvements.

Name _____ Age ❑ under 19 ❑ 19 to 40 ❑ over 40

Address _____ File No. _____

_____ Date _____

_____

Design

1. This course contains a series of Student Module Booklets. Do you like the idea of separate booklets?

_____

_____

2. Have you ever enrolled in a correspondence or distance learning course that arrived as one large volume?

❑ Yes ❑ No If yes, which style do you prefer?

_____

_____

3. The Student Module Booklets contain a variety of self-assessed activities. Did you find it helpful to be able to check your work and have immediate feedback?

❑ Yes ❑ No If yes, explain.

_____

_____

4. Were the questions and directions easy to understand?

❑ Yes ❑ No If no, explain.

_____

_____

5. Each section contains follow-up activities. Which type of follow-up activity did you choose?

- ❑ mainly extra help
- ❑ mainly enrichment
- ❑ a variety
- ❑ none

Did you find these activities beneficial?

❑ Yes ❑ No If no, explain.

_____

_____

6. Did you understand what was expected in the Assignment Booklets?

❑ Yes ❑ No If no, explain.

_____

_____

7. The course materials were designed to be completed by students working independently at a distance. Were you always aware of what you had to do?

❑ Yes ❑ No If no, provide details.

_____

_____

8. This distance learning course may include an assortment of drawings, photographs, and charts.

a. Did you find the visuals in this course helpful?

❑ Yes ❑ No Comment on the lines below.

_____

_____

b. Did you find the variety of visuals in this course motivating?

❑ Yes ❑ No Comment on the lines below.

_____

_____

9. Suggestions for audiocassette, videocassette, and computer activities may have been included in the course. Did you complete these media activities?

❑ Yes ❑ No Comment on the lines below.

_____

_____

Only students enrolled in a junior high course need to complete the following question.

10. The Student Module Booklet may have directed you to work with your teacher. How well did you work as a team?

Student's comments: _____

_____

_____

_____

Teacher's comments: _____

_____

_____

_____

Course Content

1. Was enough detailed information provided to help you learn the expected skills and ojectives?

❑ Yes ❑ No Comment on the lines below.

_____

_____

2. Did you find the workload reasonable?

❑ Yes ❑ No If no, explain.

_____

_____

3. Did you have any difficulty with the reading level?

❑ Yes ❑ No Please comment.

4. How would you assess your general reading level?

❑ poor reader ❑ average reader ❑ good reader

5. Was the material presented clearly and with sufficient depth?

❑ Yes ❑ No If no, explain.

General

1. What did you like least about the course?

2. What did you like most about the course?

Additional Comments

Only students enrolled with the Alberta Distance Learning Centre need to complete the remaining questions.

1. Did you contact the Alberta Distance Learning Centre for help or information while doing your course?

   ❑ Yes ❑ No If yes, approximately how many times? _____

   Did you find the staff helpful?

   ❑ Yes ❑ No If no, explain.

   _____

   _____

2. Were you able to fax any of your assignment response pages?

   ❑ Yes ❑ No If yes, comment on the value of being able to do this.

   _____

   _____

3. If you mailed your assignment response pages, how long did it take for their return?

   _____

   _____

4. Was the feedback you received from your correspondence or distance learning teacher helpful?

   ❑ Yes ❑ No Please comment.

   _____

   _____

   _____

   _____

Thanks for taking the time to complete this questionnaire. Your feedback is important to us. Please return this questionnaire to the address on the right.

If you are enrolled at the Alberta Distance Learning Centre and will be mailing your Assignment Booklets to ADLC, you may return this questionnaire with the final Assignment Booklet in the course.

Learning Technologies Branch
Box 4000
Barrhead, Alberta
T7N 1P4

Appendix

Glossary

Suggested Answers

Glossary

addition polymerization: a reaction in which unsaturated monomers combine (by addition) with each other to form a polymer (as the only product)

addition reactions: reactions that add atoms to a molecule across a multiple bond

biodegradable: having the ability to readily decompose in nature

carbohydrates: polymers classified as sugars, containing compounds such as glucose or fructose

condensation polymerization: a process that forms a polymer and a small molecule such as water as the products

elimination reaction: the production of multiple bond compounds through the removal of two or more atoms

enzyme: a protein catalyst

esterification: the production of an ester linkage by reacting a carboxylic acid with an alcohol

hydrocarbon combustion: the burning of hydrocarbons in the presence of oxygen

hydrogenation: an addition reaction that adds two hydrogen atoms across a multiple bond

insecticide: a substance that kills insects

polymers: large molecules made up of repeating similar subunits called monomers bonded together

polymerization: the process of making polymers

respiration: the process of carbohydrate breakdown in the body

reversible reaction: a reaction that can go in both directions

saponification: the production of soaps from the breakdown of esters

substitution reactions: reactions that involve the replacement of a hydrogen atom or functional group with another functional group

substrate: the reactant of an enzyme-catalysed reaction

Suggested Answers

Section 1: Activity 1

1. *Substitution* means to replace one thing with something else.

2. a. A halogen atom – bromine, Br – replaces one of the hydrogens.

   b. Light is required for the propane substitution reaction to occur at a noticeable rate.

   c. The following condensed structural diagrams illustrate the propane substitution reaction:

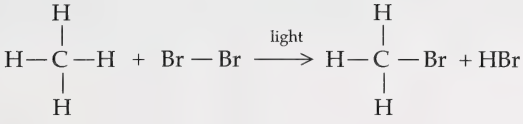
$$CH_3-CH_2-CH_3 + Br_2 \xrightarrow{\text{light}} CH_3-CH_2-\underset{\displaystyle Br}{\underset{|}{CH_2}} \quad \textbf{or} \quad CH_3-\underset{\displaystyle Br}{\underset{|}{CH}}-CH_3 + HBr$$

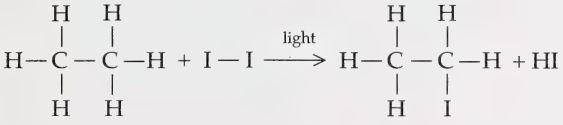
3. Benzene substitution reactions, like alkane reactions, also do not occur noticeably at room temperature. The reaction usually needs help from a catalyst (speeds up a reaction by making it easier). In benzene substitution reactions, you would also get two products, as in alkane substitutions.

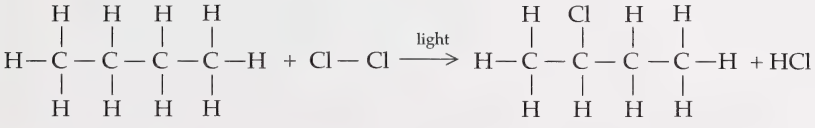
4. a. It would take three molecules of Cl_2 to substitute three atoms of chlorine.

   b. Three molecules of HCl would also be produced.

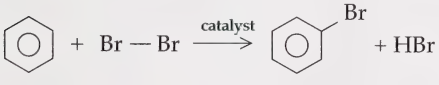
   c. $C_3H_8 + 3\,Cl_2 \xrightarrow{\text{light}} C_3H_5Cl_3 + 3\,HCl$

5. a.


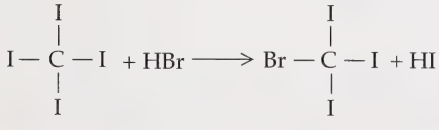
   b.


   c.


   Note: The chlorine could substitute any one of the hydrogens.

   d.


   e. $\mathbf{CH_3 - CH_3 + 2\,Cl_2} \longrightarrow \underset{\text{Cl}}{\overset{|}{CH_2}} - \underset{\text{Cl}}{\overset{|}{CH_2}} + \mathbf{2\,HCl}$

6.


7. Because of electronegativity order,

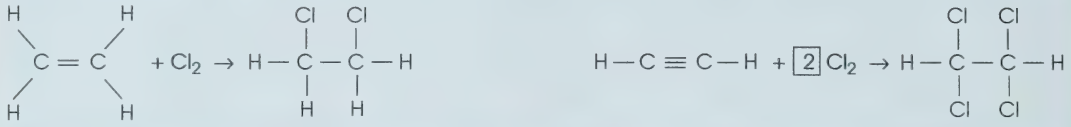
   - **F** can replace Cl, Br, or I.
   - **Cl** can replace Br or I.
   - **Br** can replace I.
   - **I** cannot replace another halogen.

8. Addition reactions are faster than substitution reactions because no strong covalent bonds must be broken. The electrons involved in the multiple bond are more reactive.

9. Hydrogen atoms and halogen atoms can be added onto multiple bonds.

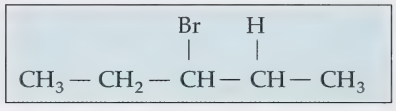
10. Alkynes can add on twice as many atoms as alkenes because of the extra bond containing two bonding electrons.

Example

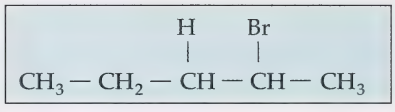


11. From least reactive to most reactive, the list should be as follows: alkanes, alkenes, and alkynes.

12. $CH_3-CH_2-CH=CH-CH_3 + HBr \longrightarrow$



or



13. A catalyst is a substance which speeds up a reaction as it participates, but is not consumed in the reaction overall.

14. a. iii
    b. v
    c. i
    d. vi
    e. ii
    f. i, iv

15. **Textbook question 14:**

    a. This is a substitution reaction.

    trichloromethane + chlorine $\xrightarrow{\text{light}}$ tetrachloromethane + hydrogen chloride

    b. This is an addition reaction.

    propene + bromine $\longrightarrow$ 1,2-dibromopropane

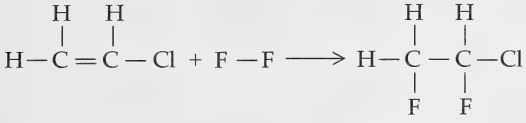
    c. This is an addition reaction.

    ethylene + hydrogen iodide $\longrightarrow$ iodoethane

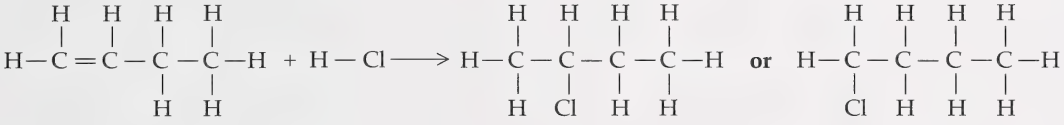
d. This is a substitution reaction.

$$\text{ethane} + \text{chlorine} \xrightarrow{\text{light}} \text{chloroethane} + \text{hydrogen chloride}$$

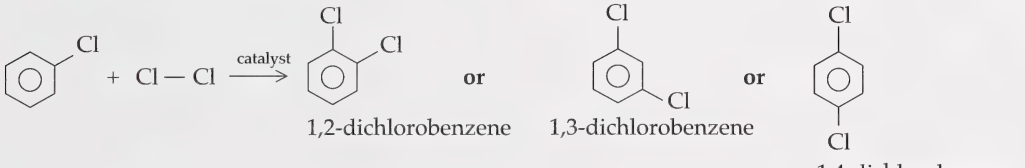
e. This is an addition reaction.



f. This is an addition reaction.

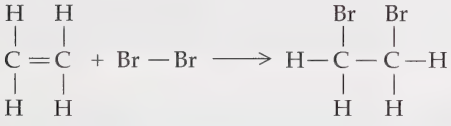


g. This is a substitution reaction.

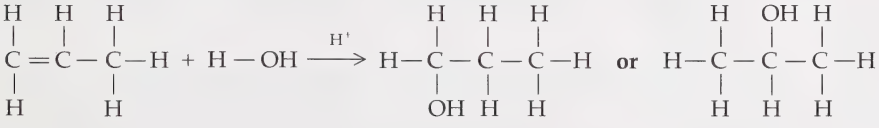


1,2-dichlorobenzene 1,3-dichlorobenzene 1,4-dichlorobenzene

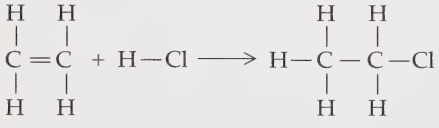
16. a.



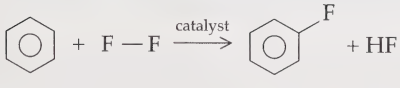
b.



c.



d.



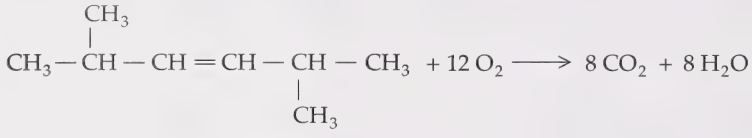
Section 1: Activity 2

1. The conditions that allow a flame to burn are as follows: materials to burn, oxygen, and ignition temperature.

2. The products of a flame are CO_2 (carbon dioxide), H_2O (water), and energy (when combustion is complete).

3. Oxygen is required to burn any substance.

4. $C_7H_{16} + 11\,O_2 \longrightarrow 7\,CO_2 + 8\,H_2O$ + energy

5. 

   2,5-dimethyl-3-hexene

6. In a fractional distillation tower, the separation of hydrocarbons is accomplished based on the differences in boiling points of the fractions. With trays at different levels in the tower, hydrocarbons with higher boiling points condense first and are collected as the vaporized crude oil travels up the tower. By heating the crude at the bottom of the tower, only hydrocarbons with low boiling points will reach the top of the tower, effecting the separation of the hydrocarbon fractions along the way.

7. *Cracking* is the breaking of large hydrocarbons into smaller hydrocarbons – about 5-12 carbons/molecule. It is accomplished by using a catalyst and/or high temperatures in the absence of oxygen. Cracking provides additional small hydrocarbons for fuel.

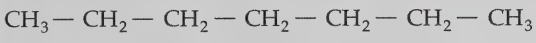
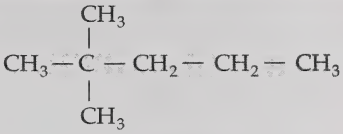
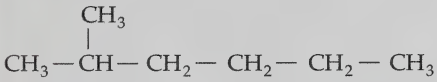
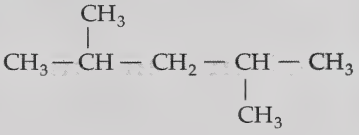
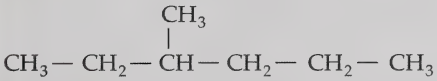
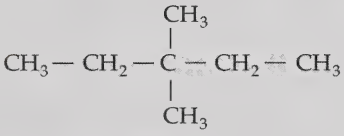
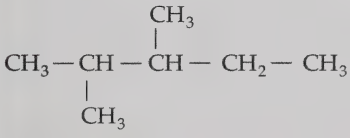
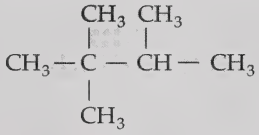
8. *Reforming* is the production of larger hydrocarbons by combining smaller hydrocarbons. This process requires a catalyst. Reforming is done to produce better fuels and create large hydrocarbons for lubricants and other petrochemicals.

9.

Reaction Type	Conditions	What Occurs
Combustion	presence of oxygen (air)	Burn hydrocarbons to produce carbon dioxide, water, and energy.
Cracking	heat, catalyst, no oxygen (air)	Large hydrocarbons are broken into smaller hydrocarbons.
Reforming	catalyst, no oxygen (air)	Small hydrocarbons combine to form larger hydrocarbons.

10. When society requires more high quality fuels the amount of cracking must increase to supply the smaller hydrocarbons used for fuels. The amount of reforming must also increase to create higher quality fuels.

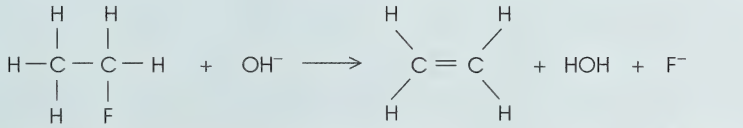
11. There are eight possible isomers.

 heptane	 2,2-dimethylpentane
 2-methylhexane	 2,4-dimethylpentane
 3-methylhexane	 3,3-dimethylpentane
 2,3-dimethylpentane	 2,2,3-trimethylbutane

12. The two types of elimination reactions involve the following:

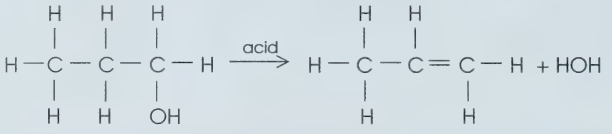
- the use of hydroxide ions (a base) to remove a hydrogen atom and halogen atom

Example (Examples will vary.)



- the use of acid as a catalyst to remove a hydrogen atom and a hydroxide ion

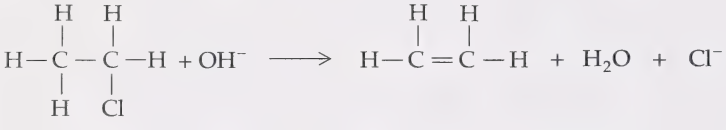
Example (Examples will vary.)



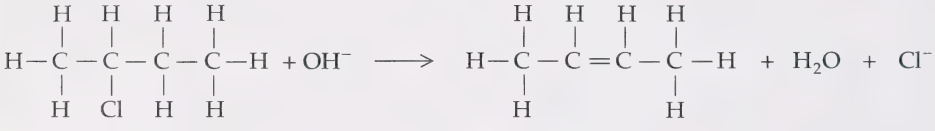
13. The common feature among the two types of elimination reactions and the dehydrogenation example is the formation of a double bond (multiple bond) by the removal of two atoms or group of atoms.

14. **Textbook question 15:**

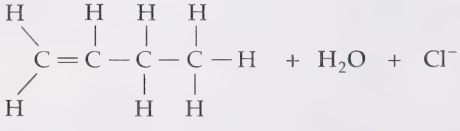
a.



b.

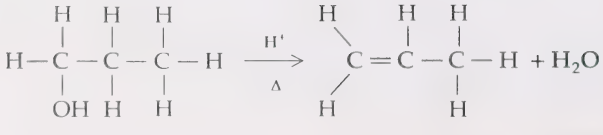


or



Textbook question 18:

a.



Note: Δ – means heat

b. $CH_3-CH_2-CH_2-CH_2-OH \xrightarrow[\Delta]{H^+} CH_3-CH_2-CH=CH_2 + H_2O$

1-butanol — 1-butene — water

15. The design should look similar to the following:

- a substitution reaction

$CH_3-CH_3 + Br_2 \longrightarrow CH_3-CH_2-Br + HBr$

ethane — bromine — bromoethane — hydrogen bromide

- an elimination reaction

$CH_3-CH_2-Br + NaOH \longrightarrow CH_2=CH_2 + H_2O + NaBr$

bromoethane — sodium hydroxide — ethene — water — sodium bromide

- an addition reaction

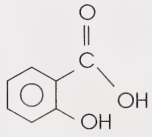
$CH_2=CH_2 + H_2O \xrightarrow[(acid)]{catalyst} CH_3-CH_2-OH$

ethene — water — ethanol

There should be no complications with the preceding procedure. The addition reaction and substitution reaction can place the *OH* or *Br* respectively on either carbon and this will not affect the product.

Section 1: Activity 3

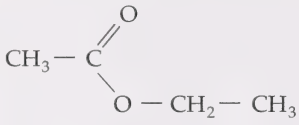
1.

Ester Formed	Structural Diagram of Reactants	Aroma
ethyl ethanoate	$CH_3-C(=O)-OH$ ethanoic acid + CH_3-CH_2-OH ethanol	solvent, nail polish remover
methyl salicylate	 salicylic acid + CH_3-OH methanol	wintergreen

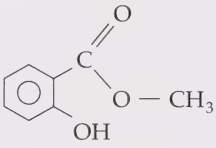
2. See the answer for question 1, Section 1, Activity 3.

3. One ester (ethyl ethanoate) could be used as a solvent. The other ester (methyl salicylate) could be used as an artificial flavouring or aroma.

4. a. By the odours you experienced in the investigation, nail polish remover and wintergreen (like sore muscle rub smell), the esters formed are the following:

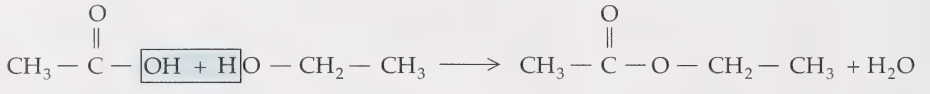


ethyl ethanoate

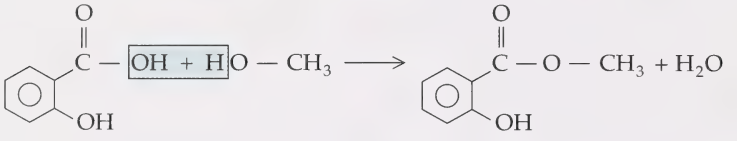


methyl salicylate

b. The two reactions that occurred are as follows:



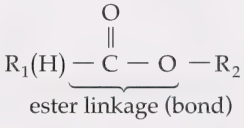
ethanoic acid ethanol ethyl ethanoate water



salicylic acid methanol methyl salicylate water

5. The molecule that is removed to form an ester is HOH or H_2O, water.

6. a. The general structural formula for an ester is as follows:



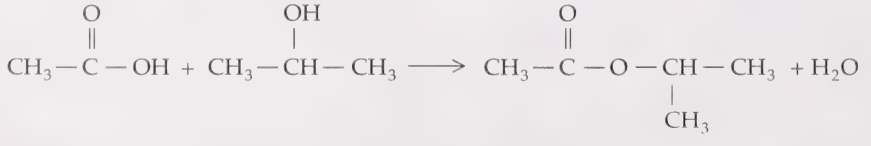
ester linkage (bond)

Reminder: R = any alkyl (hydrocarbon chain) group

b. The difference in the various esters is due to the different combinations of alcohols and carboxylic acids used.

7. Many examples are possible. The common factor in all examples should show the following:

alcohol + carboxylic acid $\xrightarrow{\text{acid}}$ ester + water. Here is one possible example:



ethanoic acid 2-propanol (isopropanol) 2-propyl ethanoate water

8. The structures of natural and artificial esters are the same, but natural esters are extracted from plant or animal sources and artificial esters are synthesized or manufactured in a lab or industrial situation.

9. Water alone would not remove the stains because the oily dirt does not readily dissolve in water.

10. To clean clothes, detergent or soap must be added to the water.

11. The observations from the investigation should be similar to the following:

    - Initially, the $NaOH_{(aq)}$ was a clear, odourless solution and the lard was a slippery, white solid.
    - Upon mixing the lard and $NaOH_{(aq)}$, the solution became creamy in appearance.
    - After 10 min, the solution started to thicken. It was poured into the milk carton mold. The solution no longer had a greasy feeling, but was still slippery.
    - After 24 h, the solution had solidified. The solid had a slippery feel to it. When mixed with water and rubbed, the solid produced some bubbles, just like bar soap.

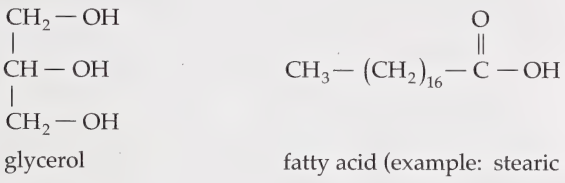
12. a. The soap changed from a liquid solution to a solid, and the greasy feeling of the lard largely disappeared.

    b. The slippery nature of the soap is largely due to the basic nature of the soap – bases feel slippery.

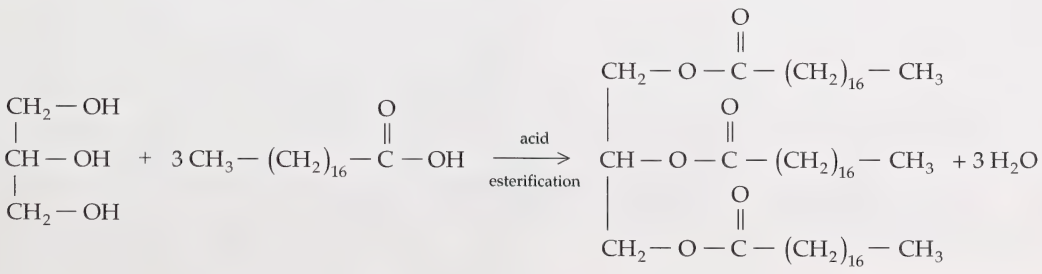
13. "Ring-around-the-collar" does not dissolve easily in water because water is a polar molecule and the collar stain is made up of nonpolar molecules. Nonpolar molecules are not attracted very well to polar molecules. The polar attraction is required for the water to wash away the stain.

14. Fats or oils are used to make soap.

15. Fats or oils are esters, made up of glycerol (1,2,3-trihydroxypropane) and three fatty acids (carboxylic acids).



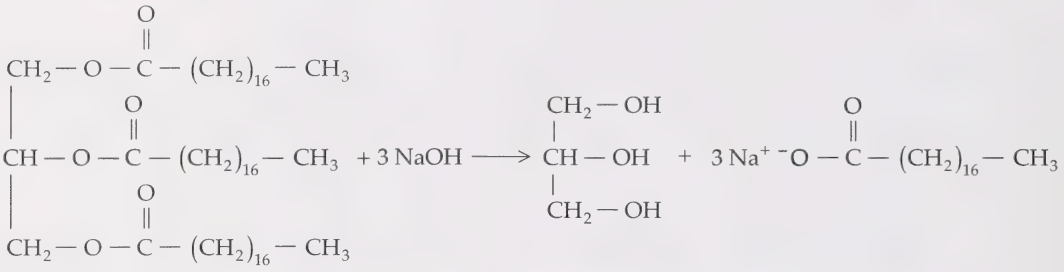
glycerol — fatty acid (example: stearic acid, $C_{17}H_{35}COOH$)



glycerol (alcohol) — stearic acid (fatty acid) — fat (triglyceride)

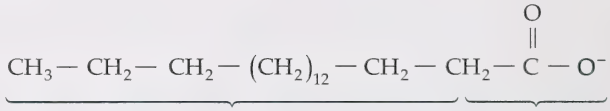
16. Soap is made by reacting fat molecules with a strong base, sodium hydroxide, in solution. The reaction, saponification, is essentially the reverse of esterification.

The ester linkage is broken between the glycerol (alcohol) and the fatty acids (carboxylic acids). The soap is an ionic combination of the fatty acid ion and the sodium ions from the base.



fat — sodium hydroxide — glycerol — soap (sodium stearate)

17. A soap molecule is able to dissolve grease stains because of its structural make-up. One end of the soap molecule is polar, the other non-polar.



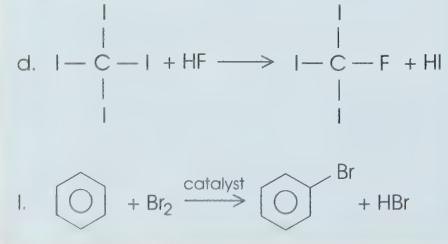
The polar end of the soap molecule allows it to dissolve in water (water molecules are polar and attract polar substances). The non-polar end seeks a non-polar environment, the grease. When enough soap molecules have been attracted to the grease (non-polar ends to non-polar molecules), the outer polar ends allow the grease to be attracted by the water (polar to polar) as small globules and get washed away.

Section 1: Follow-up Activities

Extra Help

Reaction Category: Substitution

Reaction Equations:

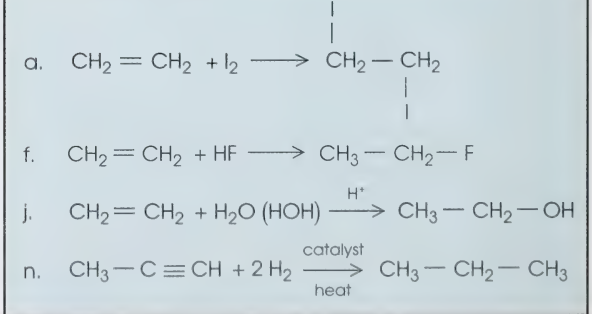


Reason:

Equations d. and l. both show the replacement of one atom by another and the production of two new products.

Reaction Category: Addition

Reaction Equations:



Reason:

Equations a., f., j., and n. all show the addition of two atoms across a multiple bond resulting in one product.

Reaction Category: Elimination

Reaction Equations:

g. $CH_3-\underset{\displaystyle Br}{\underset{|}{CH}}-CH_3 + OH^- \longrightarrow CH_2=CH-CH_3 + H_2O + Br^-$

h. $CH_3-CH_2-CH_2-OH \xrightarrow{H^+} CH_3-CH=CH_2 + H_2O$

i. $CH_3-CH_3 \xrightarrow[\text{heat}]{\text{catalyst}} CH_2=CH_2 + H_2$

Reason:

Equations g., h., and i. all show the removal of two atoms from a molecule and the resultant multiple bond in the product.

Reaction Category: Hydrocarbon Combustion, Cracking, and Reforming

Reaction Equations:

b. $C_9H_{20} + 14\,O_2 \longrightarrow 9\,CO_2 + 10\,H_2O$ + energy

c. large alkanes + $H_2 \xrightarrow[\text{heat}]{\text{catalyst}}$ smaller alkanes

m. small alkanes $\xrightarrow{\text{catalyst}}$ large, branched alkanes + H_2

Reason:

Equation b. is a hydrocarbon combustion reaction because it illustrates the burning of a hydrocarbon in the presence of oxygen; equation c. represents a cracking reaction because larger alkanes are broken into smaller alkanes; and equation m. represents a reforming reaction because smaller alkanes are brought together to form larger alkanes.

Reaction Category: Esterification

Reaction Equation:

e. $CH_3-\overset{\displaystyle O}{\overset{\|}{C}}-OH + HO-CH_3 \xrightarrow{H^+} CH_3-\overset{\displaystyle O}{\overset{\|}{C}}-O-CH_3 + H_2O$

Reason:

An alcohol is reacted with a carboxylic acid in the presence of an acid to form an ester.

Reaction Category: Saponification

Reaction Equation:

k. $CH_3-CH_2-\overset{\overset{O}{\|}}{C}-O-CH_2-CH_3 + NaOH \longrightarrow CH_3-CH_2-\overset{\overset{O}{\|}}{C}-O^- + Na^+ + HO-CH_2-CH_3$

Reason:

An ester is broken down under basic conditions to form an alcohol and a charged carboxylic acid (fatty acid) ion which can act as a soap.

Enrichment

1. Energy consumption could be reduced by several methods. Three methods currently in use or being developed are solar energy to heat homes and water tanks, wind generators to produce electricity, and electric vehicles.

   Solar energy is the most widely used alternative at present. Special glass panels can be installed on the roof of a building or be used for covering an office tower. The conventional use of solar energy is to heat stored water. This heated water can then be used for heating, for bathing, and for cleaning.

   Wind generators are currently being developed to supply electricity. Areas that do not have the opportunity to construct dams to produce electricity may have winds that can be used to supply electricity. The electricity is produced by turning a windmill attached to a generator. This form of generating power reduces the need for burning fossil fuels to generate electricity.

   One of the largest consumers of fossil fuels is the motor vehicle. The possibility of having electric cars would reduce the consumption of fossil fuels in a dramatic fashion and have the added benefit of reducing air pollution.

   The possible effect on the economy of reducing consumption would be to provide more hydrocarbons as material from which many products could be made. The increased availability of hydrocarbons could lead to an increase in job opportunities and a healthier economy.

2. Man has always used petroleum products. The early surface petroleum materials were used for many purposes including medicines, fuels, and sealants.

   It wasn't until the last half of the nineteenth century that petroleum products such as natural gas were extracted from underground. The early 1900s saw the big discovery of natural gas and naptha in the Turner Valley area of Alberta. This created a boom in exploration and population growth. The oil discovery in Turner Valley in 1936 helped immensely in World War II.

   Along with the discovery of the Turner Valley oil came the early signs of wasteful practices and their consequences. The natural gas also found at Turner Valley was wasted by burning it off. The removal of the natural gas created a lack of pressure underground which was needed to push out much of the oil reserves. Subsequently much of the oil went untapped because it couldn't be recovered.

   The post-WWII years saw the discovery of large oil reserves in the central Alberta area with the coming on-line of Leduc Number 1.

This discovery saw the beginning of a new oil era with the resulting rapid growth of Calgary and Edmonton. Calgary became the headquarters for many oil companies and Edmonton developed as the refining centre. Technology developed very quickly and saw the TransCanada PipeLines Ltd. come on-line with natural gas in 1957.

Petroleum products are found in various forms and in various locations underground. Computer technology has greater enhanced the search for petroleum reserves in recent years, but the seismograph remains the main tool for 95% of all exploration activity.

Several basic steps are followed in petroleum production from the initial acquisition of drilling rights to the use of the products by consumers. After the initial determination of site suitability, rights are acquired for drilling. The drilling process then commences with the rig setup, the drilling itself, and the assessment of the well, based on many different diagnostic tests.

A good well leads to petroleum extraction and subsequent production. The petroleum products are refined and altered to suit the demands of society. Oil is separated from gas and the separate components are purified. The gas can be used directly if sweet, or converted to valuable products such as sulphur if sour (H_2S). The oil is refined by fractional distillation, then later cracked or reformed to meet demand. The resultant petrochemicals such as ethylene can be used for the production of polymers to suit many uses.

Petroleum products must be moved from areas of supply to areas of use. Various methods include pipelines for transferring oil and gas; and rail, truck, or ship for transporting solid and liquid products.

Canadian society is very dependent on the oil industry with two-thirds of the energy in Canada coming from oil and gas. Forty-five percent of this energy is consumed in heating homes and businesses, 45% is used for transportation, and 10% is used to produce lubricants and petrochemicals.

The challenge of the future is to replace existing petroleum reserves with new technologies and frontiers. New technologies will enhance the recovery of such reserves as heavy oil and oil sands. New untapped frontiers such as the East Coast Frontier and the Beaufort Sea Frontier could provide reserves for many years to come. The exploration of these reserves and the development of required technologies is dictated by need and costs.

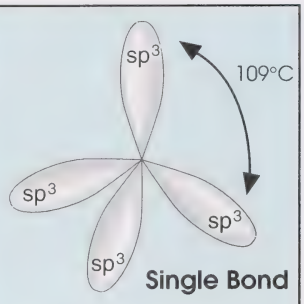
3. Bonding by a carbon atom involves forming four bonds with its four valence electrons. These valence electrons are arranged in orbitals. Two electrons are in a 2s orbital and one electron is in each of two 2p orbitals. A third 2p orbital is empty. To form four bonds of equal strength, carbon mixes one 2s and three 2p orbitals to form four hybrid sp^3 orbitals. With one electron in each orbital, this arrangement allows carbon to contribute one electron to be shared in each bond.

   When carbon forms a double bond it will only mix one 2s and two 2p orbitals to form three sp^2 orbitals, having one 2p orbital remaining. This produces a configuration that allows for three bonds of equal strength to form between atoms with the sp^2 orbitals. The remaining 2p orbital forms the second bond in the double bond. The 2p orbital occupies space above and below the plane of the molecule and is more exposed to possible reactions.

   The triple bond in carbon is formed when only one 2s and one 2p orbital mix to form two sp orbitals. Two 2p orbitals remain. One 2p orbital occupies space above and below the molecular plane as in the double bond, and the other 2p orbital occupies space on either side of the molecular plane. This arrangement exposes even more electrons to possible reactions.

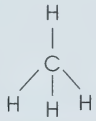
   The degree of exposure of electrons leads to the degree of reactivity of alkanes, alkenes, and alkynes: alkynes > alkenes > alkanes.

Four Single Bonds in Carbon

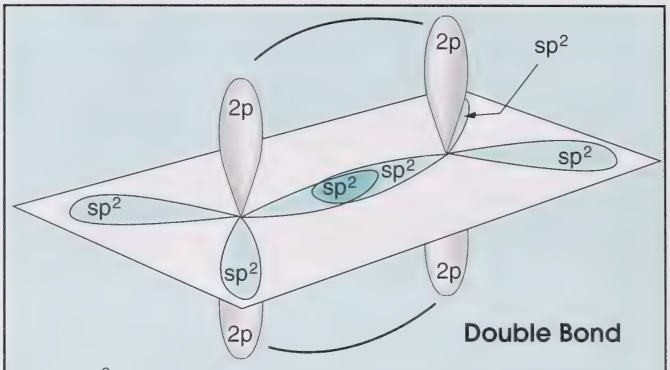


Four sp^3 orbitals form a tetrahedral shape.

Example: CH_4

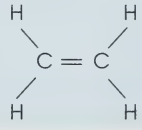


Two Single Bonds and One Double Bond in Carbon

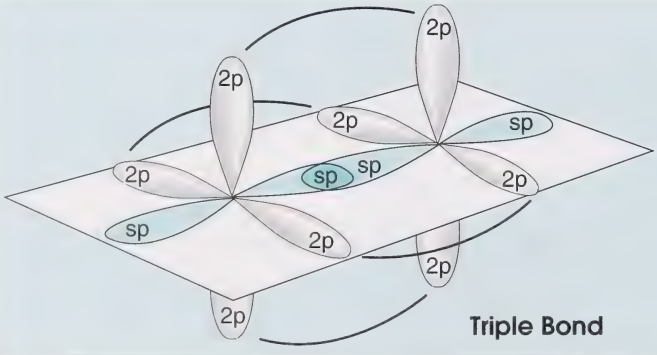


Three sp^2 orbitals form a planar shape; one 2p orbital sits above and below the plane.

Example: C_2H_4



One Single Bond and One Triple Bond in Carbon



Two sp orbitals form a linear shape; two 2p orbitals extend above, below, and to both sides.

Example: C_2H_2 **or** H—C≡C—H

Section 2: Activity 1

1. Answers will vary. There are many possibilities: vinyl tiles, plastic milk carton, paint, varnish, plastic food containers, plastic handle on a refrigerator, non-stick coating in a frying pan, windbreaker, nylon stockings, polyester shirt, acrylic sweater, plastic pen.

2. a. True

   b. False. These small molecules are called monomers.

   c. True

   d. False. Polymers do occur in nature and chemists have only been able to synthesize polymers in the 20th century.

3. a. The first polymer, a white viscous (semifluid) solid, was discovered by compressing gases such as ethylene under high pressure.

   b. The discovery of polymers had a significant effect on World War II strategies. The polymer polyethylene provided insulation for wiring which made airborne radar possible.

4. a. Polyethylene is the most widely used plastic today.

   b. Polyethylene is used in packaging film, pipes, food containers, and many other products.

5. The great variety of plastics is made possible by the different types and structures of the units that make up the polymers.

6. a. The repeating units of a polymer are called monomers.

   b. The catalyst opens up the double bond of ethylene, for example, which opens up two bonding electrons for reaction.

   This highly reactive monomer attacks other ethene molecules and attaches to them. This process then continues in a chain reaction.

7. a. The process that converts ethene to polyethene is called addition polymerization.

   b. The three factors necessary are the presence of a catalyst, high pressure (1500 atmospheres), and high temperature (250°C).

8.

Low Density Polymers	High Density Polymers
• high pressures (1500 atmospheres) • flexible plastics • benzoyl peroxide catalyst • branched chains loosely packed	• lower pressure • hard plastics • chromium oxide catalyst • linear uniform molecules tightly packed together

9. Ethene is one organic compound that can undergo addition polymerization.

10. Polyethylene can be used for plastic wire insulation, milk containers, food containers, and wash bottles.

11. The repeating units of a polymer are called monomers.

12. a. In addition polymerization the electrons in double or triple bond compounds such as ethene or ethyne are rearranged so that the monomer units can bond together to form a long chain.

    b. There is only one product, the polymer, formed in addition polymerization.

13. The properties of polymers can be made different by having different monomer structures.

14. a. Commercial addition polymers could include the following: Teflon®, Plexiglas®, polypropylene, polyvinyl chloride (PVC).

    b. Natural polymers include table sugar, insulin, and natural rubber.

15. These are the steps in polypropylene production:

    a. Crude oil is the raw material.

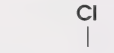
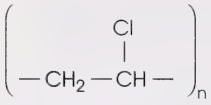
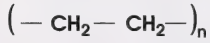
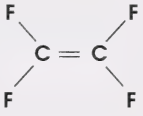
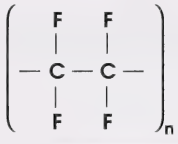
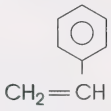
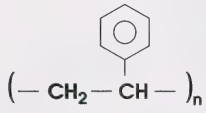
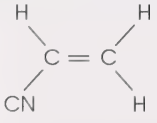
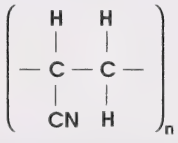
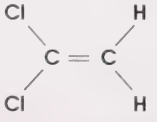
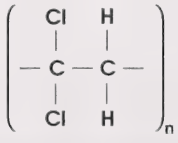
    b. The oil is refined.

    c. Polymerization is assisted by a catalyst.

    d. Extrusion of pellets from the powder takes place.

    e. The polypropylene is shipped to the processor.

16.

Monomer Structural Formula	Polymer Molecule Structural Formula	Applications
chloroethene 	polyvinyl chloride 	vinyl tile and plumbing drain pipe
ethene	polyethylene 	plastic bottles and containers, plastic bags
tetrafluoroethene 	polytetrafluoroethene (Teflon®) 	gasket material, seal for metal pipe joints, coats cooking surfaces
vinyl benzene 	polystyrene (styrofoam) 	floating devices, house insulation, insulated food containers
acrylonitrile 	polyacrylonitrile (acrylic) 	socks, sweaters (looks and feels like wool)
1,1-dichloroethene (vinylidene chloride) 	polyvinylidene chloride 	plastic food wrapping

17. a. False – Condensation polymerization requires bifunctional monomers.

    b. True

    c. True

    d. True

18. The term *bifunctional* means that a molecule contains two functional groups.

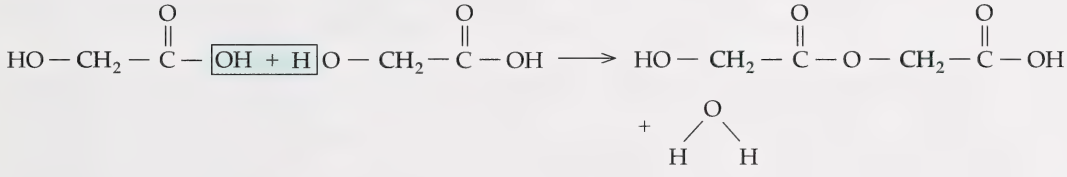
19. Examples of polyesters include Dacron®, Fortrel®, and Terylene®.

    Examples of polyamides include Kevlar® and nylon.

20. a. Yes, 2-hydroxyethanoic acid is bifunctional.

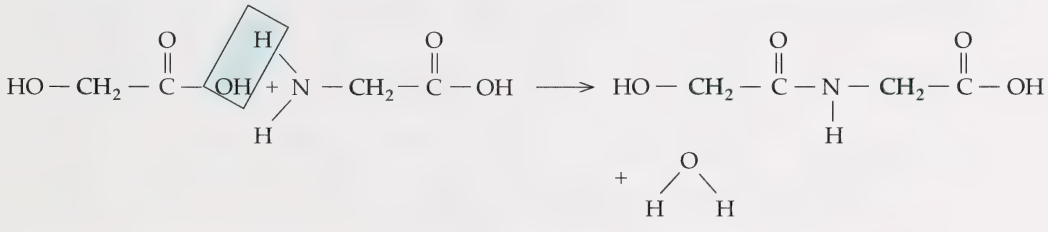
    b. The functional groups are the hydroxyl and carboxyl groups.

    c. The monomers on page 272 of *Nelson Chemistry* all have just one type of functional group; 2-hydroxyethanoic acid has two types.

21. a. 

    b. Water was produced besides the polymer.

    c. This polymer is a polyester. There is an ester linkage holding the two monomers together.

22. a. 

    b. A polyamide was formed this time because an amide linkage holds the monomers together.

    c. Water was formed as the second product.

23. a. Two example classes of natural polymers are **proteins** and **carbohydrates**.

    b. Proteins are made up of monomers called **amino acids**.

    c. Amino acids are bifunctional monomers because they have an **amino group** ($-NH_2$) at one end and a **carboxyl group** ($-COOH$) at the other end.

d. The type of polymerization used to form a protein is called **condensation polymerization**.

e. The monomer units of carbohydrates are **simple sugars**.

f. Two examples of carbohydrates are **starch** and **cellulose**.

Section 2: Activity 2

1.

Molecule	Total Energy Available (kJ/mol)	Energy Lost as Heat (kJ/mol)	Usable Energy in System (kJ/mol)	Efficiency of the System (%)
Glucose	2.80×10^3	1.03×10^3	$\mathbf{1.77 \times 10^{-3}}$	**63**
Octane	5.07×10^3	3.80×10^3	$\mathbf{1.27 \times 10^{-3}}$	**25**

2. The living system is more efficient because less energy is wasted as heat.

3. a. The conditions used by the automobile that differ from the body are the use of heat (temperature) and pressure to assist the reaction and the nonuse of enzymes.

   b. Heat and pressure aid the automobile engine in obtaining energy.

   c. Enzymes aid the body in obtaining energy.

4. The shape of an enzyme is determined by the sequence of amino acids and the intermolecular bonds between different parts of the amino acid chain.

5. The region of the enzyme involved in a reaction is called the active site.

6. Enzymes are so specific for the reactions they catalyse because only the molecules in the reaction will fit into the active site of the enzyme.

7. A living system would not be able to exist without enzymes due to the very long period of time most body reactions take without enzymes. Pressure and temperature are not available to help a living system.

8. Applications in industry for enzymes are in detergents, in the dairy industry, in breweries, and in bakeries.

9. An enzyme's purpose is to speed up (catalyse) a reaction.

10. Enzymes have sites that are shaped specifically for certain substrates – only those substrates will be attracted to the enzyme and react.

11. An enzyme is recovered after each reaction so it can be used again and again.

12. Enzymes are held in their shape by intermolecular bonds.

13. Enzymes are used for reactions in bakeries, breweries, and soap and detergent plants.

Section 2: Activity 3

1. Plastics refers to any substance that is a synthetic polymer and which can be made from a variety of raw materials.

2. To recover PET, the bottles are ground and the labels and other dry contaminants are removed. Washing removes dirt and soft drink residue. A density separation process removes metal and other plastics. Each step must be taken to prevent contamination which could alter the characteristics of PET, making it too soft or too brittle.

3. Two characteristics useful for a plastics technologist career are a good background in chemistry and physics and a willingness to continue learning.

4. Dr. Lemieux synthesized three blood group trisaccharides which eliminated the need for whole blood in blood-typing newly donated blood. Had Dr. Lemieux not been successful, blood-typing could still require whole blood for typing newly donated blood.

5. One possible lesson that you can learn is that even though you may not realize your initial dream career, don't give up. You have the potential to do many other things in life.

6. The enzyme complex is formed when an enzyme and the reacting substance bind together. The reacting substance breaks apart into the products and releases the enzyme for another cycle.

7. All enzymes perform a common function – they speed up reactions. Since they all have this purpose in common, they probably have many other factors in common. Therefore, understanding one enzyme can be of use in understanding other enzymes.

8. Maud Menten has accomplished many and varied goals in her life and has continually kept busy. She participated and succeeded in many activities outside her chosen profession.

9. Guesses will vary greatly. Assuming you don't throw your major appliances away after each use, you would still generate a lot of refuse. If you only used your clothes once, and so on, you could generate around 5-10 kg of refuse per day, including leftover food, containers, and so on.

10. An average person might generate 1-2 kg of garbage per day. Answers will vary.

11. a. You may find that one-quarter to one-half of what you throw away is plastic. Answers will vary.

    b. Much of the plastic waste generated can now be recycled into new products.

12.

Benefits	Risks
Reduce waste in landfill. Produce new, lasting products. Reduce consumption of fossil fuels. Reduce consumption of wood products. Create employment.	Pesticide residues pose a possible health hazard.

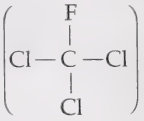
You may have a slightly different set of benefits and risks.

13. Based on the overwhelming set of benefits compared to risks, it would seem that using recycled plastic posts should be beneficial.

14. a. The magic chemical enabled the development of refrigerators, air conditioning, many types of foam plastics, aerosols, and smooth-running robots.

    b. The chemical was highly stable, nontoxic, nonflammable, and odourless.

    c. Since the chemical was nonreactive, it was thought it would have little or no effect on the environment.

15. The magic chemical was a chlorofluorocarbon, abbreviated CFC. One example is CCl_3F  .

16. a. Scientists' early theories on the detrimental behaviour of CFCs in the environment included the following proposals:

    - The CFCs would drift up into the atmosphere just above the ozone layer.
    - The CFC molecules would be blasted with UV radiation, which would release reactive chlorine atoms.
    - The chlorine atoms would react with and destroy the ozone molecules.

$$\underset{\text{chlorine}}{Cl} + \underset{\text{ozone}}{O_3} \rightarrow ClO + O_2$$

$$ClO + O \rightarrow Cl + O_2$$

free oxygen

↑ This chlorine could then react with other ozone molecules.

    b. The scientists' theory was confirmed in 1981 after an examination of the ozone layer over Antarctica.

    c. The effects of the CFCs have gradually increased and are now showing up worldwide.

17. a. Some possible effects of a depleting ozone layer include an increase in skin cancer and the destruction of much plantlife, which then results in loss of animal life and human life.

    b. Many countries are banning or have already banned the use of CFCs. Also, chemists are proposing alternate molecules with decreased amounts or no chlorine atoms.

18. Everyone must consider their actions very carefully in the present because they may have dire consequences in the future.

19.

Molecular Formula	Common Name	IUPAC Name
$CFCl_3$	Freon 11	**trichlorofluoromethane**
CF_2Cl_2	Freon 12	**dichlorodifluoromethane**
CF_3Cl	Freon 13	**chlorotrifluoromethane**
CF_4	Freon 14	**tetrafluoromethane**

20. If there were no refrigeration, you would have greater and faster food spoilage. You would not be able to choose from as great a variety of food in supermarkets because refrigerator trucks would not exist. You would not have air conditioners. Hospitals would not be able to stock blood supplies or certain drugs. Many other answers are possible.

21.

Affected Area	Effect	Result
Eyes	develop cataracts (clouding of the lens)	**reduced vision or blindness**
Skin	drying and wrinkling, burns, uncontrolled skin cell growth	**accelerated aging and skin cancer**
Immune system	reduced immune response	**increased disease infection such as cold, flu, infection, cancer, pneumonia, etc.**
Crops	interference with photosynthesis	**reduced food production**
Marine life	reduced growth of phytoplankton	**reduced food at base of food chain affecting all levels of life dependent on marine life**

Section 2: Follow-up Activities

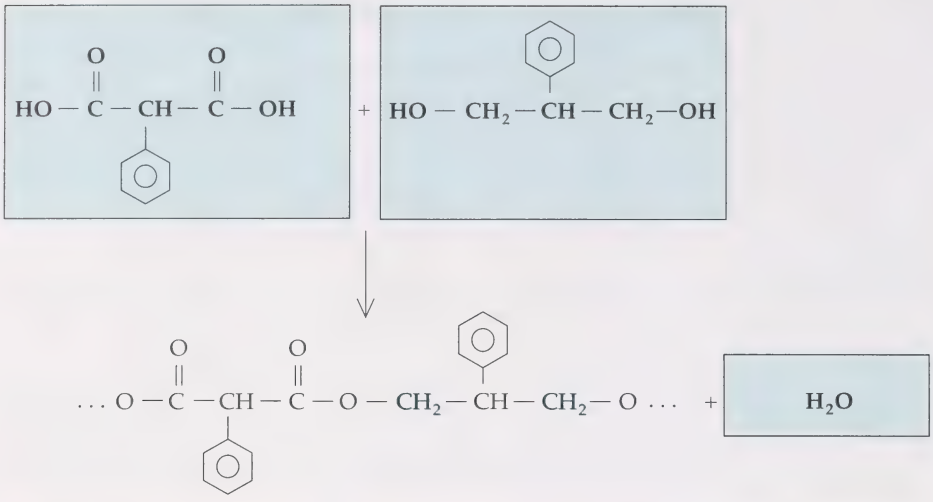
Extra Help

1. a. The construction of large molecules from smaller repeating molecules is called **polymerization**.

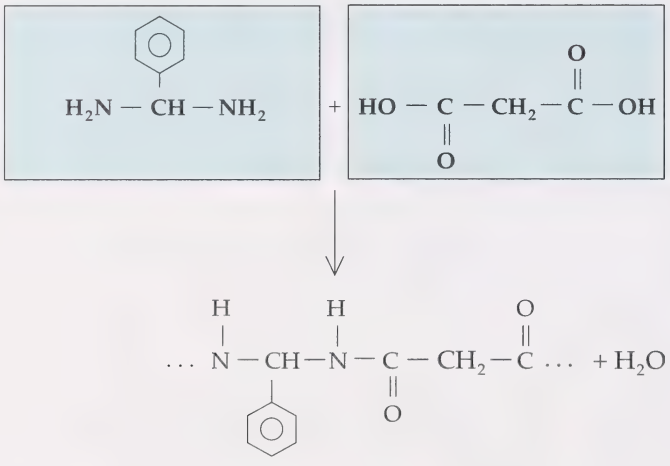
   b. The smaller molecules are called **monomers**.

   c. The large molecules are called **polymers**.

2.

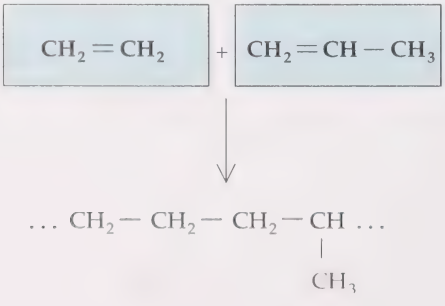


3.



4. The polymerization reactions in the preceding questions are examples of **condensation polymerization**, because both a polymer and **water** are formed.

5. a.



b. The preceding polymerization reaction is an example of **addition polymerization**.

6. Polymers can be used to make **plastic bags** and **insulation**.

7. Polymers also occur in nature. An example of a natural polymer is **protein**.

8. a. To assist a reaction, a nonliving system may use **temperature** and **pressure**.

   b. To assist a reaction, a living system uses **enzymes**.

9. Two careers that are involved with organic chemistry are **plastics technologist** and **beautician**.

10. Using organic chemistry to solve problems can have both **positive** and **negative** consequences.

11. An example of a useful group of organic molecules is the **chlorofluorocarbons**, but these molecules also may reduce the **ozone** in the atmosphere, allowing increased levels of **UV radiation** to reach the Earth's surface.

12. Ultraviolet radiation can cause **skin cancer**.

Enrichment

1. Here are some questions you may wonder about or try to answer as you play the game:

   - What are some possible conflicts that might arise in a community that is trying to place a landfill site? How might the community members avoid conflicts?

   - Are each of the factors of assessment used to rate a potential site of equal weight? Is one more important than another, and by whose standards?

2. To produce a cosmetic, the nature of skin must be understood. Skin has two general regions. The epidermis functions to protect the body. The dermis contains the sweat glands, blood capillaries, and hair follicles. The epidermis has a continuing cycle of cell generation to replace cells that are lost from the surface. To reduce cell loss and keep the epidermis soft and supple (and thereby more resistant to infection), water is supplied by the sweat glands in the dermis. The moisture is kept in by an oily layer produced by sebaceous glands surrounding the hair follicles. Dehydration of the epidermis creates cracking of the epidermis and allows infection to invade the skin.

   In creating a lipstick, the lack of sweat glands in the lips and the presence of only a few sebaceous glands has to be recognized. This condition leaves the lips susceptible to chapping and infection. Therefore a lipstick has to provide moisture and prevent dehydration. Cosmetic chemists employ two types of dyes to do this: eosine dyes that are water-soluble and lake dyes that are oil-soluble.

   The dyes are mixed in oil to create a paste. Carnuba wax is used to give form to the paste. Carnuba wax also provides a medium for transferring the dyes as the wax will hold its form until pressure is applied. At that point it melts and then resolidifies after the pressure is removed – hence the lipstick application. To improve binding of the paste to the carnuba wax, beeswax is added. Antioxidants are added to prevent the oils from going rancid and causing infection. Finally perfume is added to the mixture to flavour and scent the product.

   The production of lipstick must keep the nature of the lips in mind. The appropriate organic molecules and chemistry must be used to aid the lips in reducing dehydration and infection.

3. Answers will vary. Three examples are described here.

- One of the first synthetic fibres made was rayon. By alternating applications of caustic soda and carbon disulphide with a final neutralization process using sulphuric acid, cotton fibres were altered and extruded to form rayon threads. The rayon threads were woven into fabric that was very colourful and appeared to reflect the sun's rays, but it was not very durable.

- Probably the best known synthetic fibre is nylon. Nylon is a polyamide, $\underbrace{-\overset{\overset{O}{\|}}{C}-\overset{\overset{H}{|}}{N}-}_{\text{amide bond}}$.

  Hydrogen bonding between amide bonds on different polymers holds the polymers together to form threads. The threads are twisted into yarns. The yarns are twisted and stretched to four times their original length by a machine called a drawer. This technique maximizes the hydrogen bonding between the polymers and increases flexibility and strength. The flexibility and strength of nylon allows for its use in many products. Examples are hosiery, garden hoses, clothing fabrics, backpacks, tents, rope, and tires.

- Carbon-carbon fibre is a synthetic that has futuristic applications. Synthetic yarns are woven into a three-dimensional shape and then coated in metal or plastic. This array is then carbonized (coated in carbon) at very high temperatures, 650°C-1100°C, in a nitrogen atmosphere. The coating and carbonization are repeated several times and pressure and heat are continually increased, up to 2500°C. This technique causes the carbon to form sheets of fused benzene rings. The fabric is very strong due to the extensive network of covalently bonded carbons, the double bonds in the benzene rings and the metal or plastic coatings in the fabric. The fabric goes through a final machining to form the finished product. Such products are used heavily in the aerospace industry and include many products from structural components of spacecraft to spacesuits.

© 1993, 2001